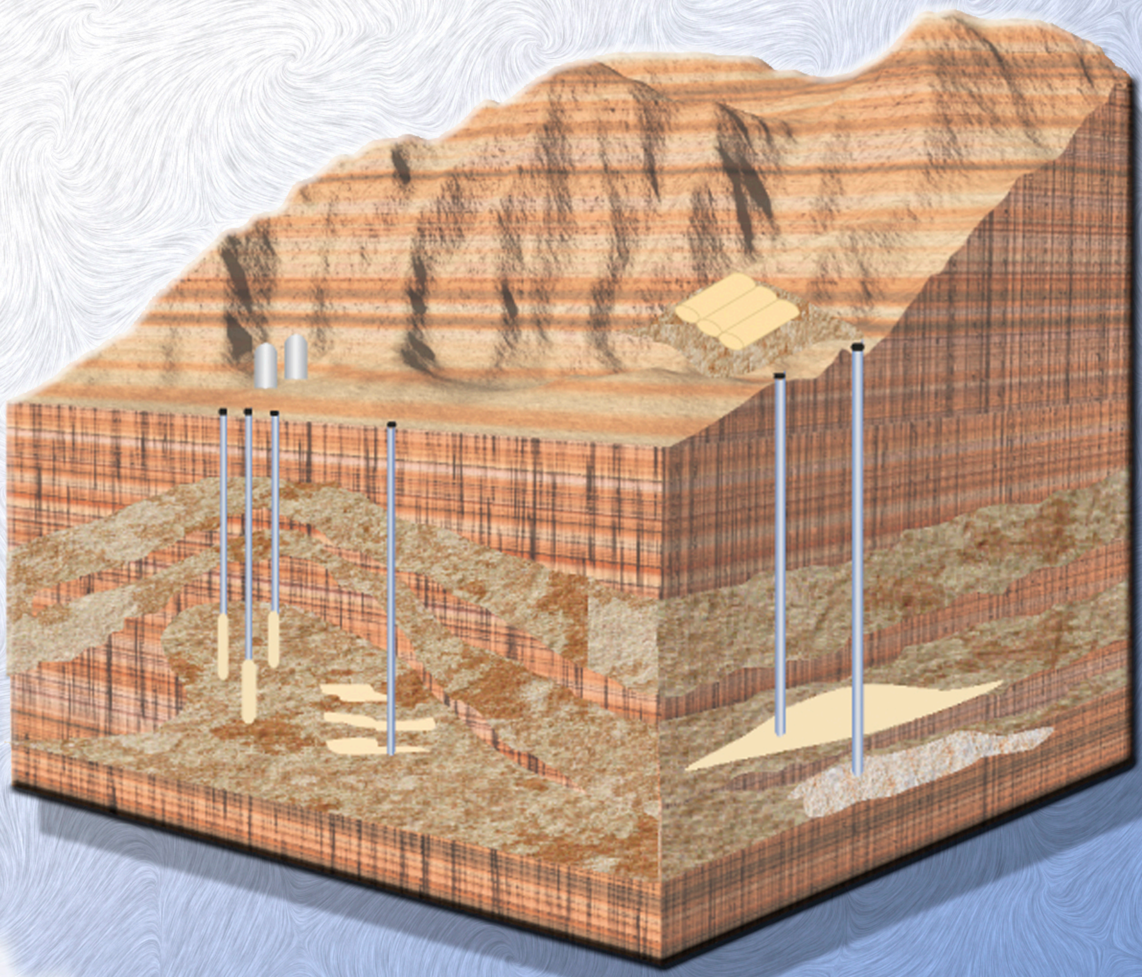
Natural Gas Storage Workshop Proceedings

November 29, 2001 • Pittsburgh, Pennslyvania



U.S. Department of Energy
National Energy Technology Laboratory
Strategic Center for Natural Gas

Disclaimer

Contents

SECTION 1.0
Introduction

1.1 OVERVIEW

The U.S. Department of Energy's National Energy Technology Laboratory (DOE/NETL) hosted a one-day collaborative workshop on Natural Gas Storage research and development (R&D) in Pittsburgh, Pennsylvania, on November 29, 2001. The purpose of the workshop was to develop a roadmap of the technologies needed to improve conventional storage field performance and to supply the anticipated demand for natural gas to fuel power generation plants using advanced storage concepts. Participants were asked to recommend priorities for natural gas storage R&D and to explore ways in which DOE can collaborate with industry and others to accomplish priority R&D in public/private partnerships.

The information gathered on industry's technical challenges and needs will help provide a foundation for a roadmap to guide natural gas storage R&D in industry and government and to guide R&D solicitations. Identifying and developing these solutions will ensure that the U.S. natural gas storage infrastructure will continue to meet the needs of consumers for decades to come.

1.2 WORKSHOP PROCESS

Fifty-one participants from 39 organizations representing a cross-section of interests and expertise from industry and academia participated in the workshop (see Appendix B). Discussions of technology challenges, needs, and actions took place in three separate facilitated groups. Two groups focused on conventional storage issues, while the third group concentrated on gas storage for power generation and remote off-pipeline issues. Each group developed a list of challenges and barriers to improved natural gas storage. Participants then developed opportunities for R&D that could provide means of overcoming these barriers. The top R&D needs were selected through a consensus process, and implementation strategies were developed for each. These strategies include the following: component R&D activities and steps; capabilities, tools, facilities, and resources; collaborations, partners, and government role; geographic benefits; and impacts for deliverabiliy and cycling, cost savings, safety and security, capacity, environmental, and reliability.

1.3 WORKSHOP RESULTS

1.3.1 Summary

Figure 1 summarizes the results of the three work groups. Integrity assessment and reservoir characterization are major crosscutting R&D needs among the groups. The development of new methods for creating storage reservoirs with proof-of-concept testing and reservoir management including optimization are prevalent, too. Each of these needs is discussed below.

Integrity needs should address the technical risk associated with the long-term geotechnical integrity of bedded salt caverns including deformation and roof leaks. Component activities include failure analysis and definition, with inspection and monitoring feedback for better assessment and control. Other integrity issues deal with development of advanced casing inspection tools capable of assessing pipe condition for metal loss and remaining strength. Component activities include developing correlations between log interpretations and strength of materials to determine wellbore integrity. Better integrity assessment would have positive safety and environmental impacts.

Reservoir characterization R&D should evaluate capacity and deliverability with an emphasis on using seismic technology applications for better characterization and monitoring with coupled reservoir and surface simulators. Integration of industry technologies could attack the problem. For example, E&P tools could be applied to storage problems by reversing the focus from production to injection and cycling issues. Advanced data interpretation will help identify damage and optimize performance. Potential impacts for deliverability, cost, capacity, and reliability are enormous for all locations, both new and old.

New methods for creating storage reservoirs must be pursued, although the cost impact will likely to be minimal given proof-of-concept development expenses. The continued R&D into lined rock caverns is warranted given successful breakthroughs in Sweden and feasibility progress. Other potential new methods include thermal re-excavation and liquefaction and new locations such as abandoned coal mines.

Reservoir management R&D should develop a method for brine disposal and prevent and handle hydrates formed during operations. Activities include basic chemistry, computational flow and fluid dynamics, and thermodynamic studies. There would be good cost savings with brine disposal. Development of a downhole barrier to gas migration would have a beneficial impact on capacity, and it would be widespread especially for aquifer operations.

Work-Group Topics	High-Priority R&D Areas of Opportunity
Conventional Gas Storage – Group A	• Characterization using seismic • Downhole barrier to gas migration • Hydrates management • Brine disposal • Pipe integrity assessment
Conventional Gas Storage – Group B	• Pipe integrity assessment • New methods for storage • Evaluation of capacity and deliverability • Automated field operating systems
Gas Storage for Power Generation & Remote Off-Pipeline	• Geotechnical integrity of caverns • CNG for Distributed Generation (DG) • Regulatory relief from FERC • Injectability cycling research

Crosscutting Issues

- **Integrity Assessments: Piping metal loss, strength, metallurgy, etc.; Salt cavern failure analysis for roof leaks, deformation, etc.**
- **Resource Characterization: Integrate seismic technologies to improve base gas/working gas ratio, assess damage, etc.; Turnaround E&P tools for injection.**
- **New Methods: Create storage reservoirs like lined rock, thermal re-excavation, liquefaction, etc.**
- **Management & Optimization: Automated field operation systems need instrumentation, communication, data management, etc.; Develop brine technologies for disposal, salt production, etc.**

Figure 1. Overview of Gas Storage Workshop Results

1.3.2 Key Challenges and Barriers

The past decade has brought about significant changes to the natural gas storage industry. Due to environmental restrictions, natural gas has become the fuel of choice for new power plant developments, particularly to meet summer peaking loads. As a result, the injection season has become longer and cycling rates have become higher. Growing consumer demand and unpredictable weather fluctuations have increased market volatility. Storage operators are required to stretch the limits of their aging facilities beyond their original design capabilities to meet these needs. Despite the growing demand and increasing gas prices, the industry is wary of investing capital to build new storage due to the uncertainty and risk involved. All of these factors have challenged the status quo within the natural gas storage industry. However, they also present new opportunities for growth for the industry.

Reservoir Characterization

Identifying and characterizing reservoirs continues to present a major challenge to the expansion of storage capacity. Three-dimensional seismic technology is expensive and does not adequately characterize formation properties, such as heterogeneities. Nor does it identify gas-filled porous bodies in reef structures. Unconventional storage reservoirs hold promise; however, more data are needed before they can be used in commercial operations. Plus, they often need expensive modifications before they can be useful.

Wellbore Integrity

Damage at the wellbore can cause unpredictable effects, resulting in downtime and lost revenue. The source and mechanisms of wellbore damage are not well understood because of the lack of tools available to collect data. Wellbore condition is not frequently monitored because of the lack of diagnostic techniques.

Reservoir Management

Reservoir management encompasses a wide range of issues. For instance, high levels of expensive cushion gas are needed to ensure deliverability. Inventory levels are difficult to verify without downtime, and non-intrusive monitoring systems are unavailable. Gas migration poses safety hazards as well as lowers the efficiency of the system. Gas hydrate formation is not well understood, and hydrogen sulfate removal is quite expensive. Furthermore, the operation and maintenance costs to maintain the integrity of aging facilities are rising at an incredible rate.

Market Conditions & Regulatory Environment

As mentioned above, consumer and industrial demand is growing at a steady pace. However, the market continues to show significant volatility due to weather unpredictability and other factors. Regulations on the power generation industry deter utilities from building storage reservoirs. Air emissions limitations restrict injection, and reservoir pressures are limited in most states, reducing storage capacity. The cost of pipeline use is on the rise for utilities, who must compete with entities whose expenses are often subsidized.

Cycling and Injectability

The current natural gas storage infrastructure was originally designed for seasonal service, not for year-round injection and withdrawal. Existing facilities were not designed to handle short-notice injection or withdrawal. Injection flow rates are limited by pipeline constraints. Furthermore, skin damage in high rate storage wells limits peak rates.

1.3.3 R&D Priorities and Implementation

The research priorities delineated here, if developed and implemented, promise to help the natural gas storage industry to surmount the tremendous obstacles they currently face and to guide them successfully into the future. While all the research opportunities available hold value, four in particular surface as the top research priorities. These priorities possess the most potential in addressing the industry's needs over the next fifteen years. The descriptions here also outline the key technical elements needed to achieve each goal, as well as the resources and collaborations critical to implementing the strategy. Government, industry and academia all have a role to fill in accomplishing these objectives and ensuring the reliability of the natural gas storage infrastructure for years to come.

Top Priority Research Needs
➢ Develop advanced methods of assessing, monitoring and improving wellbore and geotechnical integrity.
➢ Develop innovative and non-intrusive techniques to identify, characterize and enhance storage reservoirs.
➢ Develop means of optimizing field operations through automation, hydrates control, and improved base gas to working gas ratio.
➢ Develop cost-effective solutions to the technical issues affecting the unique natural gas storage needs of the power generation industry.

R&D Priority

Develop advanced methods of assessing, monitoring and improving wellbore and geotechnical integrity.

Description	Key Technical Elements
Wellbore integrity continues to be a critical factor in natural gas storage operations, particularly as existing sites begin to age. In order to significantly improve operations, the industry needs advanced methods of economically assessing and monitoring characteristics of wellbore integrity, including metal loss, stress (delta pressure), remaining strength, and other parameters of pipe condition. Enhanced inspection tools that could immediately identify and diagnose problem areas would prevent accidents, reduce downtime, and increase overall reliability. Further, an analysis of the primary sources and mechanisms of wellbore damage, as well as research into methods of preventing this damage and improving wellbore integrity, would enhance the lifespan of existing and future storage reservoirs. Advanced materials specifically designed for storage applications would further improve the strength and longevity of wellbore structures.	• Baseline study of wellbore damage mechanisms and impacts, particularly on deliverability • Benchmark evaluation of current inspection and monitoring tools • Development and dissemination of best practices for preventing wellbore damage • Piping thickness surveys and metallurgical analyses • Development of correlations between log interpretations and materials stress and strength • Advanced data interpretation • Strength of materials modeling • Non-destructive evaluation and other techniques to determine the type and extent of wellbore damage • Remote sensing technologies • Design parameter characterization • Advanced materials research • Demonstration projects

Implementation Strategy

Resources	Government Role	Potential Partners
• Tool research • Industry logs • Burst test results • Pipe correlation data	• Provide funding • Coordinate research • Technology transfer • Facilitate implementation	• American Petroleum Institute • Interstate Oil & Gas Compact Commission • American Society of Mechanical Engineers • Society of Petroleum Engineers • Southwest Research • Battelle • Universities • Service companies • National laboratories

R&D Priority

Develop innovative and non-intrusive techniques to identify, characterize and enhance storage reservoirs.

Description	Key Technical Elements
Expanding the roster of storage reservoirs is essential to ensuring the future supply of available natural gas for residential and commercial use. New technologies must be developed that can economically and non-destructively locate and identify geologic formations that would serve as good storage reservoir candidates, including rock caverns, aquifers, salt caverns, and man-made structures such as abandoned mines. Once these formations have been identified, seismic and alternative technologies are needed to characterize the various properties of the structure, such as capacity, porosity, and permeability, and assess its value as a storage reservoir. Lastly, economic methods of altering the structure to make it more suitable to natural gas storage would enhance its efficiency and significantly add value to the reservoir. Some of these techniques include brine disposal methods, sealing methods, refrigeration and thermal re-excavation. These developments would open up a vast array of new storage sites, optimize existing storage efficiency, and reduce the geographic imbalance of available storage across the U.S.	• Geographic benchmark/baseline study • Regional geological feasibility cost-benefit analyses • Controllable, non-surface seismic and alternative, non-invasive technologies • Remote sensing technologies • Fine-resolution geophysical modeling and simulation • Sealant materials studies • Brine disposal methods • Development of excavation techniques • Refrigeration research • Reservoir performance optimization studies • Diagnostic techniques to identify good stimulation candidates • Demonstration projects

Implementation Strategy

Resources	Government Role	Potential Partners
• Geological studies • Drilling techniques research • Reservoir models	• Provide funding • Coordinate research • Technology transfer from Department of Defense	• U.S. Geological Survey • State geological societies • Universities • Construction and operating companies • State agencies • National laboratories

R&D Priority

Develop means of optimizing field operations through automation, hydrates control, and improved base gas to working gas ratio.

Description	Key Technical Elements
Reservoir management presents a continuing challenge and increasing expense for the natural gas storage industry. High base gas to working gas ratios reduce deliverability; lowering cushion gas requirements would increase the available supply of natural gas across the country. Discovering and demonstrating lower-cost, alternative cushion gases would also make more natural gas available for use. Automating system operations in order to monitor inventory levels, gas migration, hydrate development, and reservoir pressure and capacity would significantly reduce down-time and improve the cost-effectiveness of storage operations. Developing advanced barriers to gas migration would minimize the amount of gas lost to the environment, thereby improving the safety and reliability of the system. Hydrates formation also complicates operations substantially; methods of preventing and handling hydrates would also contribute to improving the industry. Integration of these techniques in order to optimize field operations would go a long way in ensuring the ability of the U.S. natural gas storage infrastructure to meet future demands.	• Survey and analysis of existing field practices • Developments in instrumentation, communication technology, and remote sensing technologies • Advancements in data storage, integration, mining, analysis, and overall management • Applications of artificial intelligence to natural gas storage operations • Material and chemical studies of candidates for gas migration barriers • Studies of barrier placement • Computational fluid dynamics analyses • Research into the phase behavior and formation of hydrates • Optimization studies • Long-term geotechnical integrity studies • Injection and cycling studies • Reservoir management model • Demonstration projects

Implementation Strategy

Resources	Government Role	Potential Partners
• Basic chemical studies • Flow loop studies • Field test results • Artificial intelligence • Process controls	• Provide funding • Coordinate research • Technology transfer	• Computational Fluid Dynamics Consortium • Chemical companies • Universities • Storage field operators • National laboratories • Software developers

R&D Priority

Develop cost-effective solutions to the technical issues affecting the unique natural gas storage needs of the power generation industry.

Description	Key Technical Elements
The power generation industry's requirements for natural gas storage differ significantly from residential and commercial consumers. Electric peaking loads demand higher cycling and injection rates than conventional uses. These loads have strained existing storage reservoirs beyond their technical design limitations. Studies are needed to assess the long-term impacts of these uses and to develop measures to prevent damage. Design parameters need to be developed so that the existing infrastructure can be retrofit to accommodate the power industry's needs and so that new storage can be constructed to withstand these pressures. Proximity to power generation facilities has recently become a necessity as more gas-fired plants have been built and transportation more limited. Advances in on-site compressed natural gas storage would improve the cost-effectiveness of this option. Economic incentives and relaxing of regulatory limitations would allow power generators to develop nearby underground storage reservoirs. Support for distributed generation infrastructure would put the energy source closer to the end-user, thereby minimizing losses and improving efficiency. Economic models to optimize commodity transportation and storage would enhance the power generation industry's efficient use of natural gas and minimize strains on the country's storage infrastructure, ensuring the future availability of the resource.	• Development of pipeline, dispatch and storage models • Economic optimization models • Sensitivity analyses • Cycling and injection impact assessments and reservoir models • Development of design parameters for power generation's storage needs • Research on compressed natural gas storage options • Regulatory and policy analysis • Distributed generation and compressed natural gas marketing feasibility studies • Technology transfer between production and storage applications • Advanced control systems for more flexible injection and withdrawal cycles • Risk assessment tools • Demonstration projects

Implementation Strategy

Resources	Government Role	Potential Partners
• ISO regional studies • Economic models • Industry logs	• Provide funding & incentives • Coordinate research • Regulatory development	• State regulators • Office of Economic Development • FERC • Pipeline and storage companies • EPA

SECTION 2.0

Plenary Session: Presentations

This section provides the presentations given by DOE/NETL Product and Project Managers in the workshop's plenary session. These presentations provide an overview the gas storage technology areas, partnership approaches, and successes. In addition, there were five presentations by industry executives that provide a variety of perspectives on the future demand and requirements for natural gas storage. Please note that one of the industry speakers did not use any slides, so his presentation cannot be duplicated herein.

National Energy Technology Laboratory
Strategic Center for Natural Gas

Natural Gas Storage R&D Planning Workshop

Hyatt Regency
Pittsburgh, PA
November 29, 2001

Brad Tomer, Product Manager
Gas Exploration, Production & Storage

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NETL

- **One of DOE's 15 national laboratories**
- **Government owned and operated**
- **Sites in Oklahoma, Pennsylvania, West Virginia**
- **1150 federal and support contractor employees**
- **Primary focus is managing external Fossil Energy R&D**

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2K-2345 BJT 12/00

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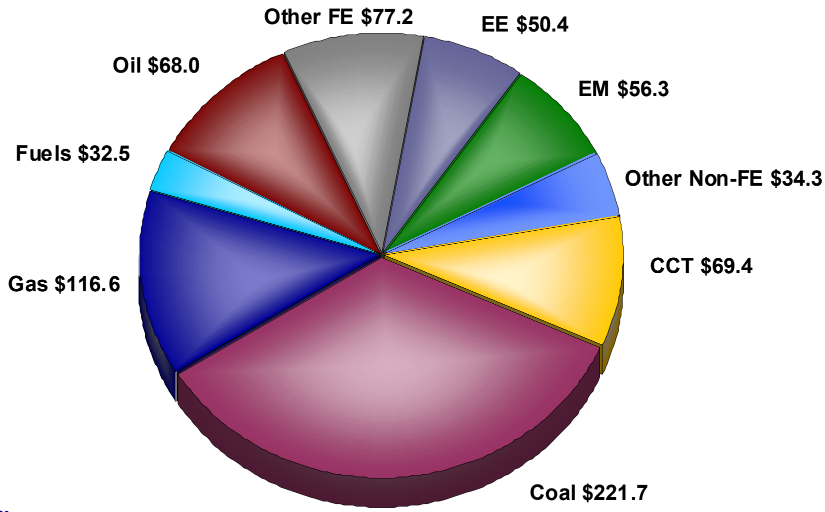
NETL FY01 BUDGET
($726.6 Million)



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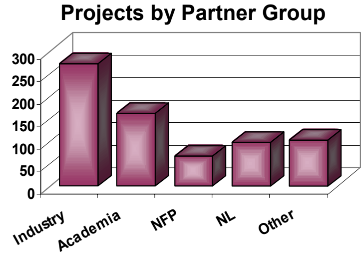
Shape, Fund, and Manage Extramural RD&D

- **Over 800 research activities in all 50 states and 16 countries**
- **Total award value of $7.3 billion**
- **Research performers include:**
  - Private industry
  - Universities/colleges
  - Not-for-profit labs
  - Other DOE national labs
  - Others
- **Private sector cost sharing of $3.9 billion**
  - Leverages DOE funding
  - Ensures relevance
  - Mission accomplishment only through commercialization
- **55 active MOU's and MOA's**

Projects by Partner Group



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Five RD&D Activity Clusters

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Borehole to Burner Tip

Electric Power Using Coal
Mining to Light Switch

Energy Policy Support
A Key Issue in Use of Fossil Energy

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Environmental Quality/ Defense Programs
Supporting the DOE Complex

Oil Supply

Fuels

Supply and Delivery of Clean Fuels for Transportation/Other End Use Sectors

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Vision:

By 2020, U.S. public is enjoying benefits from an increase in gas use:

- Affordable supply
- Reliable delivery
- Environmental protection

Mission:

Be the focal point for an integrated gas program:

- Spearhead annual DOE-wide gas RD&D planning and program assessment
- Shape, fund, and manage extramural RD&D
- Provide science and technology advances through NETL's on-site programs
- Conduct studies to support policy development

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SCNG's Technology Portfolio

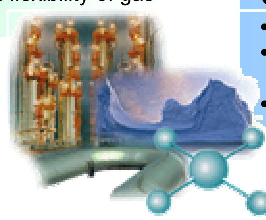
Borehole to Burner Tip

Next Generation Gas Turbines for Large Industries / Utilities
- Flexible 30-300 MW turbine systems
- RAM improvements
- Supporting R&D

Distributed Generation
- PAFC - entering commercial market
- MCFC - high efficiency
- SOFC/SECA - low cost
- Hybrid turbine/fuel cell - ultimate efficiency
- Reciprocating engines - lowest cost

Gas Infrastructure Reliability
- Enhance pipeline safety and reliability
- Increase gas deliverability
- Increase operational flexibility of gas storage facilities

Gas Exploration & Production
- Resource and reserve assessments
- Improved diagnostic, imaging, drilling and completion technologies
- Hydrates, deep gas, off-shore



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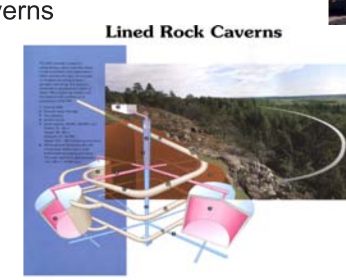
Gas Storage Technology Areas

- **Conventional Storage Reservoirs**
  - Deliverability enhancement
  - Gas measurement
  - Reservoir management
- **Advanced Storage Concepts**
  - Lined Rock Caverns
  - Hydrates
  - Salt Caverns
  - Basalt Aquifers



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Gas Storage R&D Planning Workshop

- **Purpose**
  - Obtain industry perspective
  - Identify key barriers & R&D opportunities
  - Develop collaborative R&D action plan for next 2-5, 5-10, 10-15 yrs
- **Breakout Sessions**
  - Conventional A&B: Deliverability enhancement, reservoir & facility mgmt, inventory control from aquifers, depleted oil & gas reservoirs, salt caverns
  - Power/Distributed Generation: Gas storage to meet electric generation needs including alternative storage technologies
- **R&D Challenge**
  - Meet industry needs -Collaborative in nature
  - System mindset -Product focused

NETL 2K-2345 BJT 12/00

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Options for Continued Industry Participation

- **Advisory Panel**
  - Hydrates program
- **Roadmapping**
  - Infrastructure, hydrates, and many others
- **Cooperative Agreements**
  - Joint industry projects, individual firms, etc.
- **Industry-Driven Consortium**
  - Advanced turbines, carbon products, SWC
- **National laboratory partnership**
  - NGOTP, hydrates, ultra-clean fuels

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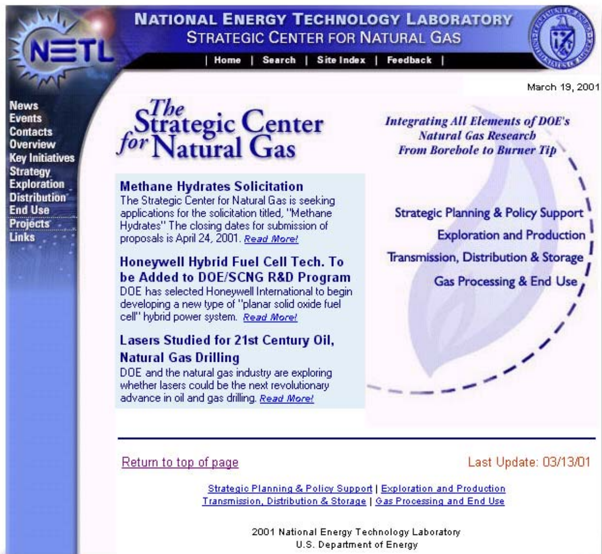

Internet Location: netl.doe.gov/scng/index.html

2K-2345 BJT 12/00

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Natural Gas Storage R&D Planning Workshop

Thank You For Participating

2K-2345 BJT 12/00

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Natural Gas Storage R&D Program

Natural Gas Storage Workshop

November 29, 2001

James R. Ammer, Project Manager
Gas Supply Projects Division

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Future Needs for Storage

- **1999 NPC Study predicts that by 2015**
  - 38,000 miles of new transmission line
  - 263,000 miles of distribution mains
  - 0.8 Tcf of new working gas storage capacity
- **Tremendous growth in electric generation**
  - larger off-peak swing loads
  - peak-day requirements will increase from 111 Bcf/d to 152 Bcf/d
- **Growth in areas without conventional storage**
  - Northeast
  - South Atlantic

National Petroleum Council, Dec 1999

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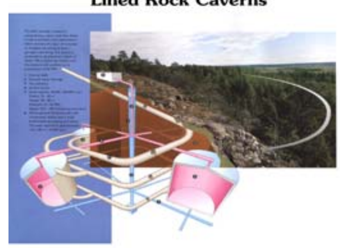
Gas Storage Technology Areas

- **Conventional Storage Reservoirs**
  - Deliverability enhancement
  - Gas measurement
  - Reservoir management
- **Advanced Storage Concepts**
  - Lined Rock Caverns
  - Hydrates
  - Salt Caverns
  - Basalt Aquifers

Lined Rock Caverns



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Partnership Approach

- **R&D conducted with various partners**
  - Industry (Bay Gas Storage,Furness-Newburge)
  - Other research organizations (Gas Technology Institute, Southwest Research Institute)
  - National labs, universities and industry associations
- **Cost shared projects are common**
  - Field tests (National Fuel Gas, Kinder Morgan, NiGas)
  - Development of technologies (Baker Atlas)
- **Technology transfer**
  - Cooperative agreements with commercializing partner
  - Successful field demonstrations
  - Petroleum Technology Transfer Council

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Conventional Storage Reservoirs

Deliverability Enhancement

Deliverability RD&D Timeline

- **1993 GRI - Maurer study set stage**
  - 5% annual deliverability decline; $60 million to $100 million remediation costs
- **GRI/DOE co-funded Halliburton project completed in 1998 identified major damage mechanisms**
- **DOE/GRI co-funded project completed in 1999 introduced novel stimulation treatments**
  - 29 treatments conducted in 8 fields
  - documented water sensitivity and candidate selection
- **DOE research investigating new remedial technologies**
  - sonic tool for scale removal
  - carbon dioxide treatments for HOPS damage

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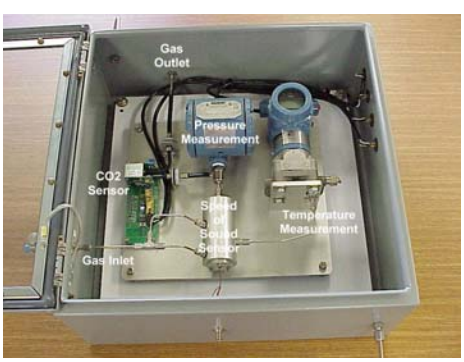
Conventional Storage Reservoirs

Gas Measurement

Energy Meter Retrofit Module Prototype



- Low cost retrofit module
- Inferential approach uses gas properties
- Transmission tariff gas
- Accuracy equivalent to gas chromatograph
- Use with any flow meter

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Energy Meter Retrofit Module Prototype
Status

- **Developed algorithm for energy meter**
  - extended diluent concentrations to 20%
- **Designed and constructed prototype module**
- **Conducted initial testing at MRF**
- **Complete refinement in 2001**
- **Complete MRF and field testing by 2002**
- **Desired accuracy - 1 Btu**
- **Pursue commercialization**

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Conventional Storage Reservoirs

Reservoir Management

DOE Simulation Studies

- **Demonstrate the importance of geologic modeling and reservoir simulation for improved storage efficiency with an emphasis on horizontal wells**
- **Initiated in 1992**
  - no horizontal wells in storage (reported)
  - little to no use of simulation
- **Today**
  - >40 horizontal well
  - mix of simulation use
- **Published 3 SPE papers, 2 DOE reports**

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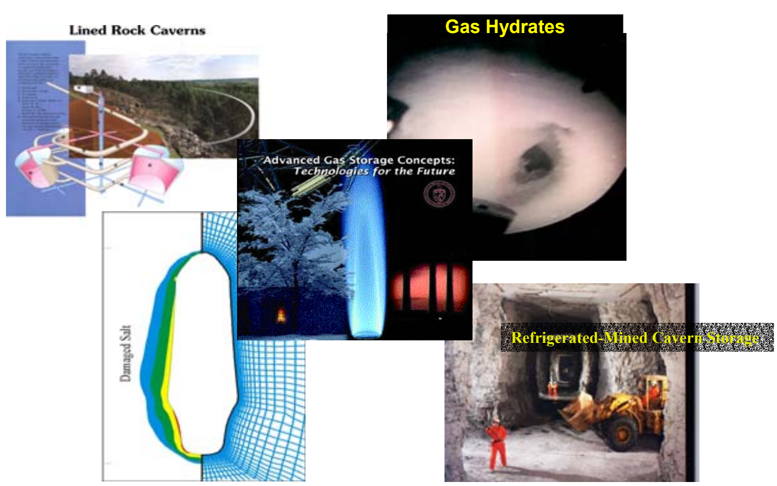
Advanced Storage Concepts



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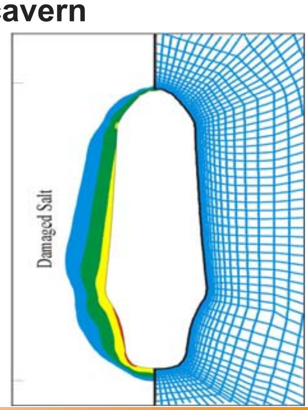
Advanced Design For Salt Caverns Proof-of-Concept

- Field-scale application of advanced design criteria
- Existing and new salt storage cavern
- McIntosh Salt Dome
- Mobile, Alabama
- RESPEC
- Bay Gas Storage Company



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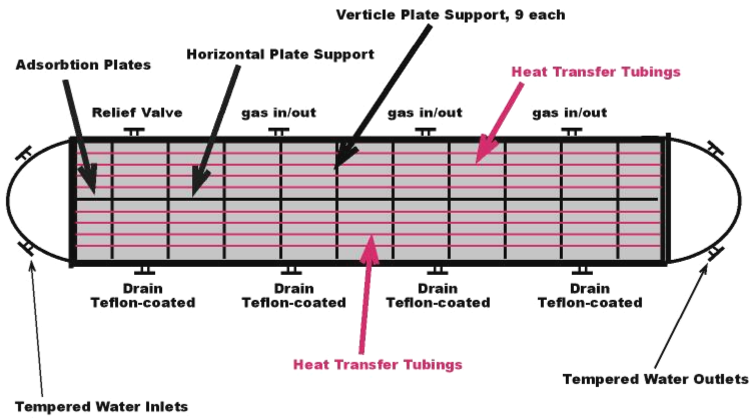
Hydrate Gas Storage - Scale Up

- Initial testing conducted in 39 cc cell
- New work will scale to 20 gallon tank



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LRC Design Review

- Technical review of Lined Rock Cavern concept and design methodology
  - Independent review
  - Itasca Consulting Group, Inc.
- *Mechanical Response of Rock Mass* completed September 2001
- *Steel Lining: Fatigue and Crack Growth* to be completed by June 2002

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Gas Storage in Basalt Aquifers
Columbia River Basalts

- **Columbia Basin spans 63,000 sq. mi**
  - nearly 13,000 ft of layered Miocene lava flows
  - individual flows covering over 27,000 sq. mi
- **Regional aquifers are confined between lava flows**
- **Flow tops are vesicular and very porous**
- **Anticlinal structures provide excellent targets for gas storage**

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Basalt Characterization

- **Drilled the 100 Circles # 1 Well July 1999**
  - drill samples collected and analyzed
  - geophysical logs run
- **Drilled second borehole**
  - Approximately 150 feet from 100 Circles #1 Well
  - Conducted well to well flow tests
- **Acquired and processed 2-D seismic**
  - structural closure and areal extent
- **Hydrologic testing and groundwater chemistry**
- **Final Report and data sets due June 2002**

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Successes

- **Deliverability Enhancement**
  - Introduced novel stimulation technologies
  - Developed a prototype Sonic Tool for scale removal
- **Advanced Storage**
  - Completed feasibility study of 4 advanced concepts
  - Completed design review for LRC: *Mechanical Response of Rock Mass*
- **Gas Measurement**
  - Developed energy meter algorithms, initiated testing, commercialization likely
- **Reservoir Management**
  - Published 3 SPE papers, 2 DOE reports

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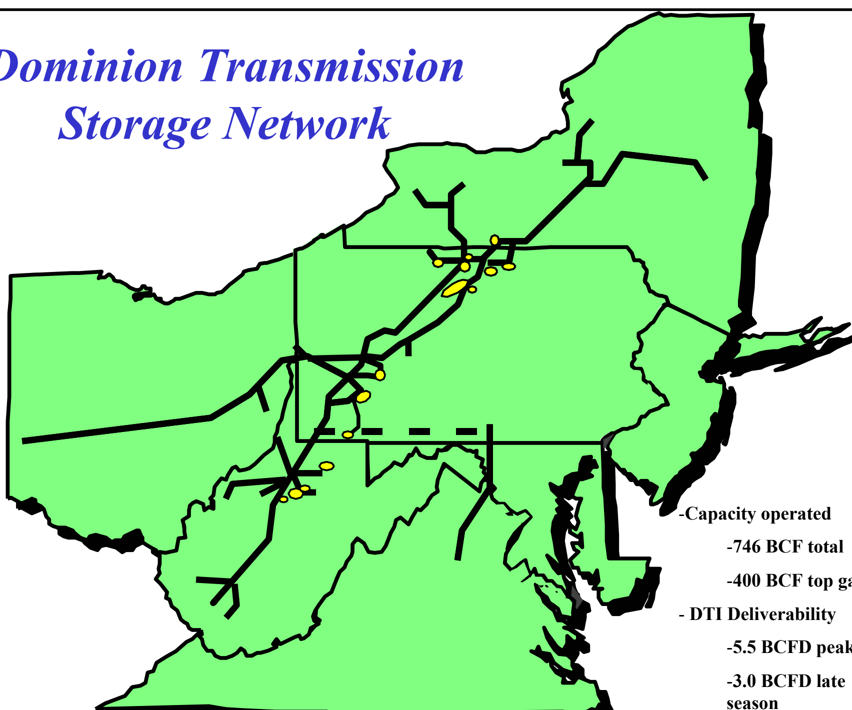
Department of Energy Natural Gas Storage R&D Workshop

Dominion Transmission
Gary L. Sypolt
Sr. Vice President
November 29, 2001

Dominion
It all starts here:

Dominion Transmission Storage Network



- Capacity operated
  - 746 BCF total
  - 400 BCF top gas
- DTI Deliverability
  - 5.5 BCFD peak
  - 3.0 BCFD late season

Dominion Transmission Storage Stats

- Total wells 1508
- Average depths 1400 ft-7000 ft
- Reservoir Pressures 500psi-4200psi
- Storage HP 207,265

Perspectives of Future Gas Storage needs within the Industry

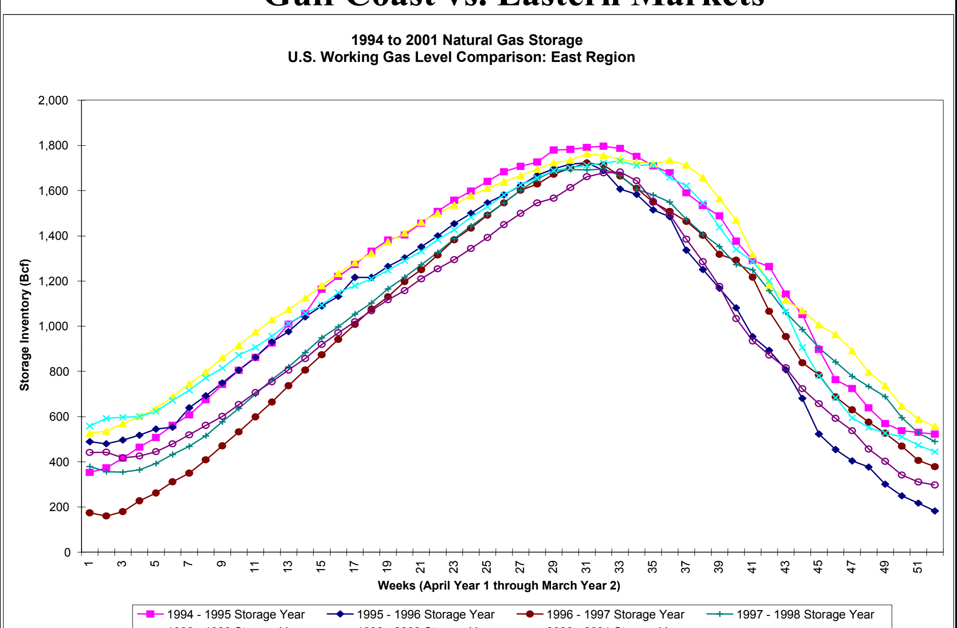
Perspectives of the future are shaped by knowledge of ***what's worked in the past*** connected to the ***creative possibility of the future*** and tempered with the realities of the ***competitive options in the marketplace.***

DOE Workshop Issue

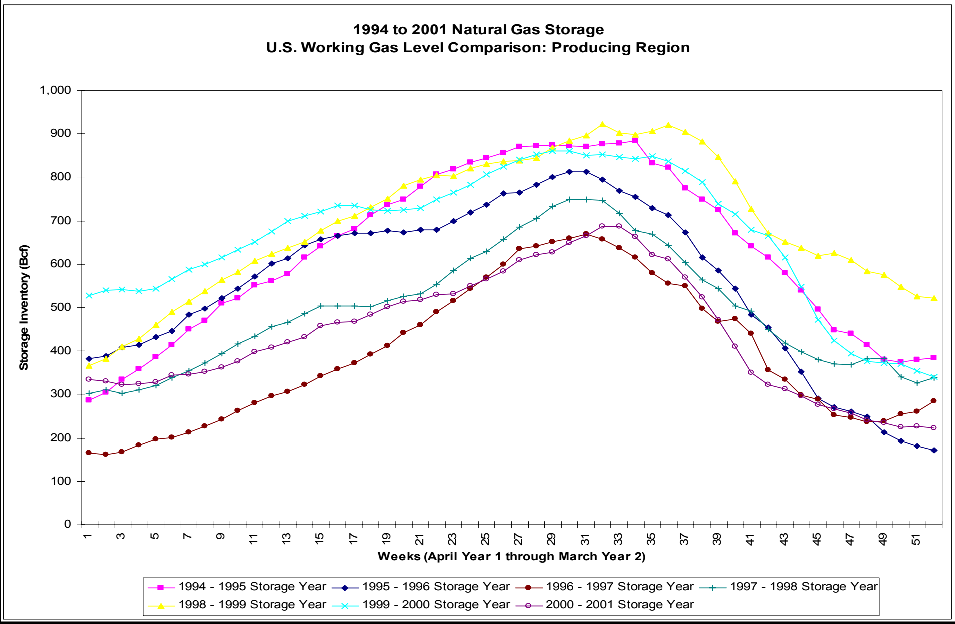
Is the the existing natural gas storage infrastructure adequate to meet current needs?

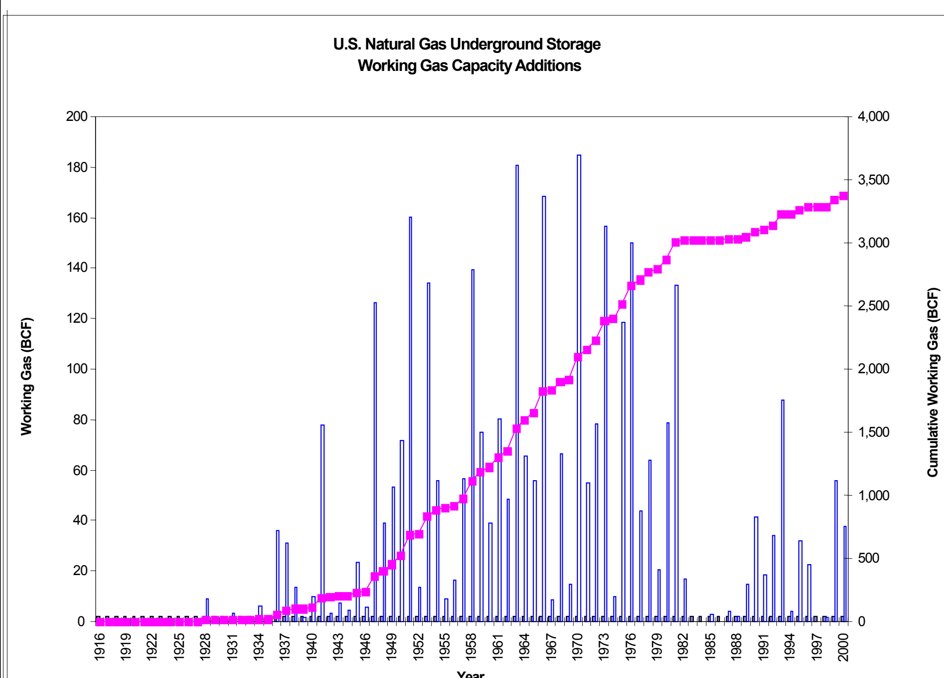
Dominion
It all starts here.

Gas Storage Utilization within the Industry Gulf Coast vs. Eastern Markets



Gas Storage Utilization within the Industry
Gulf Coast vs. Eastern Markets





Gas Storage Infrastructure

- **In total**
  - **444 storage projects**
  - **3.4 TCF capacity**
  - **82 BCF / day**
- **Since 1990**
  - **55 storage projects**
  - **440 BCF capacity (13%)**
  - **16.6 BCF / day (20%)**

Dominion
It all starts here.

DOE Workshop Issue

What market and technology trends are likely to change storage needs over the next ten years?

Dominion
It all starts here.

Market Trends Dominion's View

- Market demands more flexibility in storage service
  - Asset managers
  - Marketing companies
  - LDC unbundling (shifting)
- Power Generation market will grow and will require gas storage for load balancing
- Clean air regulations will force fuel conversion creating more storage opportunities

Dominion
It all starts here:

Market Trends Dominion's View

- Storage development activity will be driven by cost
- Customers continue to look at locational value of storage
  - alternative to holding firm transportation on long line pipelines from Supply area
  - Total delivered price is what matters
- Gas Storage further promotes the liquidity
  - Gulf Coast
  - Eastern Market
- Storage will help all customers capture value created by volatility in gas prices

Dominion
It all starts here:

Technology Trends
Dominion's View

- Storage developers will look to technology to help improve deliverability
  - Reengineering of reservoir storage
    - Existing
    - New
  - Salt storage
  - Mined storage
  - LNG
- Storage operators and developers will look to technology
  - Reduce operating costs
  - Maintain integrity of the infrastructure
  - Reduce storage gas loss

Dominion
It all starts here.

Potential Barrier

Cost to develop and operate

Dominion
It all starts here.

Potential Barrier

Regulation (uncertainty of Local, State and Federal)

Dominion
It all starts here:

Potential Barrier

Cost effective transportation capacity to market

Dominion
It all starts here:

Potential Barrier

Did I mention cost to develop and operate

Dominion
It all starts here:

Natural Gas Storage: Opportunities and Challenges

Rick Daniel

President, AEC Storage and Hub Services Inc.

for U.S Dept. of Energy workshop, Nov.29, 2001

AEC

GROWTH VALUE PERFORMANCE

AEC Storage and Hub Services

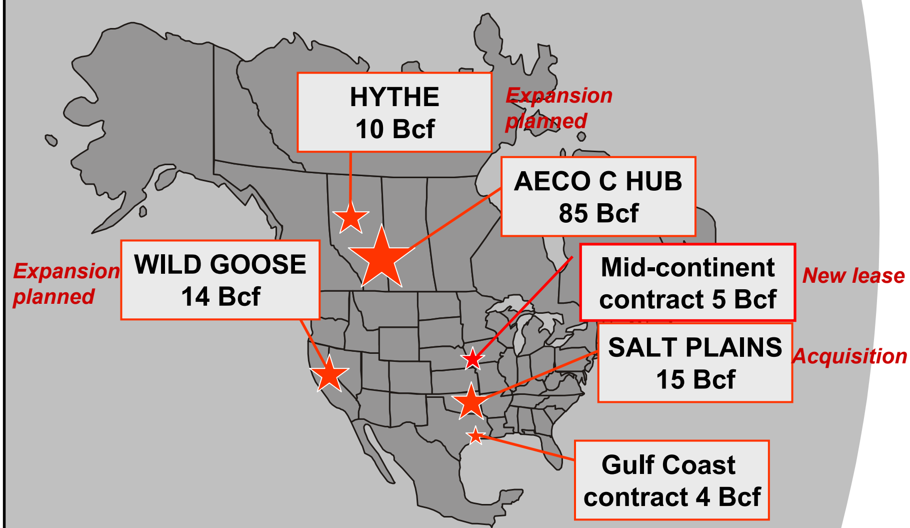
- Business unit of Alberta Energy Company Ltd.
  - Largest producer of Canadian natural gas
  - Among the largest North American independents
    - 1.4-1.5 Bcf/day in 2001
- Committed to growth in independent gas storage business, through development, expansion, acquisition and contracting:
  - own and operate 124 Bcf WGV
  - 9 Bcf of contracted capacity

AEC

GROWTH VALUE PERFORMANCE

AEC Storage and Hub Services

AEC



GROWTH VALUE PERFORMANCE

Opportunities and Hurdles for Storage Developers

AEC

Opportunities:

- Tight supply, price volatility increases storage value
- Gas-fired power gen needs storage for reliability, flexibility
- Growing gas market
  - storage can be alternative to overbuilt pipeline system

Hurdles:

- Volatile cushion gas costs, fuel costs
- Most storage services still too highly regulated
- Urban sprawl, NIMBY issues

GROWTH VALUE PERFORMANCE

How Much New Capacity is Required?

AEC

GROWTH VALUE PERFORMANCE

- NPC study of market growth 1998-2015:

U.S. gas consumption +42% (22 Tcf to 31.3)

↓

Peak day demand +37% (111 Bcf to 152 Bcf)

↓

Storage capacity +25% (3.2 Tcf to 4 Tcf)

Actual storage needs difficult to forecast:

- competes with DSM, fuel switching, in meeting peak demand

Where will new storage capacity come from?

AEC

GROWTH VALUE PERFORMANCE

Probable economic ranking of opportunities:

- Optimization of existing facilities
  - commercial
  - technical
- Expansion of existing facilities
  - new pools, caverns
- Storage substitution: replace existing, inefficient facilities, with new capacity in same market
- New, incremental facilities

Salt Caverns or Reservoirs?

AEC

- Perception that salt caverns can best meet the needs of the market:
  - high deliverability
  - low ratio of cushion gas to working gas
- Reservoir storage developed with current upstream technology can provide similar service at lower cost:
  - identification of high quality reservoirs
  - horizontal wells
  - 3D seismic
  - reservoir, facility optimization

GROWTH VALUE PERFORMANCE

Too Much Capital Tied Up in Cushion Gas

AEC

- Ratio of Cushion Gas to Working Gas:
  - Salt Cavern facilities 0.37
  - AEC's reservoir storage 0.36
  - All other US storage 1.10
- Over 4 Tcf of cushion gas in older reservoir, acquifer facilities
- Opportunities:
  - blow down, replace with more efficient facilities
  - re-develop with modern upstream technologies

GROWTH VALUE PERFORMANCE

Further De-regulation of Utility Storage Required

- Owners of utility storage assets need incentives to optimize
- Utility shareholders must benefit from:
  - a) innovative services that more fully utilize existing capacity
  - b) technical optimization of capacity
  - c) reduction of cushion gas
- More timely regulatory processes
- Alternative: divestment of storage assets, contracting for storage services

GROWTH VALUE PERFORMANCE

Gas Storage Development Conclusions

- Storage values increasing, but few new projects
- High M&A activity in independent storage
- Storage development increasingly a ‘technology’ play
  - no “low hanging fruit”
- Storage ‘re-development’ has potential
- Over-regulation discouraging investment, rationalization of capacity
- Capacity additions likely to lag demand

GROWTH VALUE PERFORMANCE

FALCON GAS STORAGE

Perspective on the Future of the US Natural Gas Storage Market

Presented to:

U.S. Department of Energy

National Energy Technology Laboratory

Natural Gas Storage R&D Workshop

Pittsburg, PA

November 29, 2001

FALCON GAS STORAGE COMPANY, INC.

- Independent, merchant owner, developer and operator of high develiverability, multi-cycle (“HDMC”) storage capacity.
- Founded October 2000.
- Company focus: redevelop depleted oil/gas reservoirs in market areas (ERCOT, NERC, WSCC/RM) for HDMC service.
- HDMC capacity in service (Hill-Lake, Eastland Co., TX):
  - MSQ: 8,500,000 Dth (12 Bcf Total)
  - MDWQ: 150,000 → 300,000 Dth/d
  - MDIQ: 100,000 → 150,000 Dth/d
- Interconnects: TXU Lone Star “X” and “WA”, EPG/TXU N. Texas Pipeline.
- Additional projects in N. Texas, New York and RM.
- Formed Greyhawk Gas Storage Co., LLC with subsidiary of Emera, Inc. in 2001 to develop HDMC storage in NE.

Trends Impacting US Gas Storage

- Growth in GFEG → incremental load profile will be "spikier" at the margin.
- Domestic reserve replacement slowing . . .
- Growing Canadian imports → shifting "null points".
- Mismatch in incremental supply and demand volatility → increased price volatility at the margin.
- Tightness in midstream capacity → higher weather sensitivity.
- Daily balancing → deliverability and injection vs. working gas.
- EFM and similar technology → ability to match gas and power dispatch more closely (but can the reservoirs respond?).
- Consolidation of mid-stream asset ownership → lower cost of capital, but less customer choice (?)
- Lots of announcements, not many projects.

FALCON GAS STORAGE

Market Needs

- **Needs vary significantly within market segments.**
  - LDCs, Marketers, Pipelines, Power Gen, Producers
- **More withdrawal capacity needed for peak hours.**
  - Human needs, arbitrage, pipeline balancing, power dispatch.
- **More injection capacity needed for off-peak hours.**
  - Dispatch at a loss or shut down?
- **Proximity to market area.**
  - Balancing pressure swings vs. locational optionality.
- **Cost vs. Utilization** (HDMC reservoir vs. Salt).
  - What's optimal? For whom?
  - 4x – 6x in the market area offers optimum capacity for diverse needs (seasonal, arbitrage and balancing).

FALCON GAS STORAGE

Existing Barriers to Development

- **Market Apathy, Uncertainty:**
  - "It's worked so far."
  - Market's sense of urgency related to last season's weather.
  - Lack of GFEG interest (background, economy, "free swing").
  - Cost center vs. profit center mentality.
  - Contract terms (short vs. long, fixed vs. variable).
  - Shifting null points on the grid.
  - Regulatory uncertainty.
- **Constraints on new supply:**
  - Scarce, finite supply of suitable reservoirs.
  - Profit center vs. cost center mentality ("Show me the money").
  - Lack of risk capital.
  - Low asset turnover.
  - NIMBY political power.

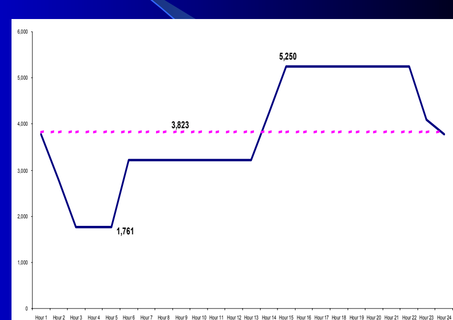
- **Result**: Expansions vs. New Projects.

FALCON GAS STORAGE

New GFEG Demand

What the incremental customer is asking for. . .

- Expected Load Profile: 5 x 16.
- 750 MW @ 7,000 heat rate = 5,250 Dth/hour.
- Base load supply @ 3,823 Dth/hour.
- Seeks intra-day (hourly) balancing.
- Pipeline unable to provide firm balancing – charging penalties for interruptible service.
- "How much do I need ??"
- "How much does that cost?"



FALCON GAS STORAGE

Capacity Math

Question: How much optionality desired?
(daily, monthly, seasonal)

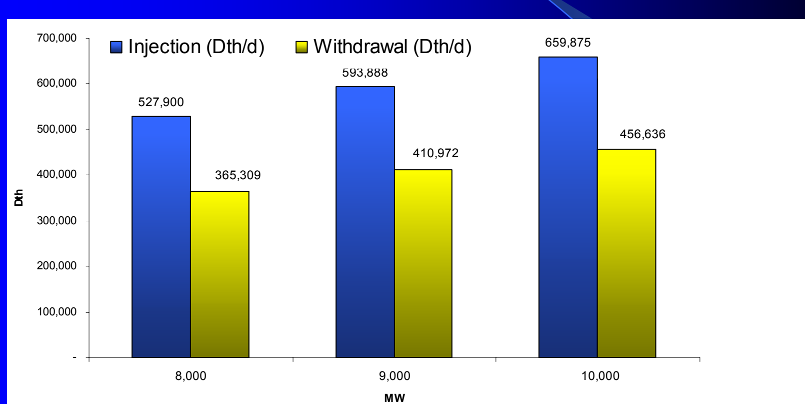
MDIQ = (Hourly Baseload – Minimum Hourly Burn) x 24
MDWQ = (Max Hourly Burn – Hourly Baseload) x 24
MinSQ = Sum of injection (or withdrawal) over 24 hr period.

- Desired ratio of injection and withdrawal to working gas is extremely high.
- Customer sees little incentive to carry "extra" inventory.
- Fuel managers may have different incentives.

FALCON GAS STORAGE

Example Market in Texas

8,000 - 10,000 Incremental MW Growth @ 7,000 Heat Rate



FALCON GAS STORAGE

How much does that cost?

- 9,000 new GFEG MWs @ 7,000 heat rate.
- Injection/withdrawal capacity required:
  - MDIQ: 600,000 Dth/d
  - MDWQ: 400,000 Dth/d
  - MSQ: ???
- @ $300 - 400/Dth/d = Capital Investment of $120 - 240 MM (does not include the cost of capital).
- Note: Assumes suitable reservoirs are available close to relevant pipelines exist.

FALCON GAS STORAGE

Summary

Conclusions:

- Latent demand for storage cycling capacity is growing.
- Latent demand is being masked by transient conditions.
- Uncertainty, lack of incentives, regulation and Mother Nature will restrain new development of injection and deliverability as long as demand remains latent.
- Required investment is very large and will be a surprise to many.

Open Questions:

- Supply and Demand *will* balance, but at what price?
- When does capital begin to flow into the storage segment and at what cost?
- How will the risks of high fixed costs be allocated among developers, operators and customers?
- Who has better ability to lower the risk/cost of capital?

FALCON GAS STORAGE

Predictions

- Expansion projects will supply majority of incremental capacity through 2005.
- New long-haul transport capacity will not solve the problem.
- Many new storage projects will be announced, very few will be built.
- Greater % of GFEG will effectively become peakers.
- GFEG capital providers will require LT FSS.
- More joint-ventures, sale/lease-back deals.

performance

raised to the power of El Paso

Byron Wright

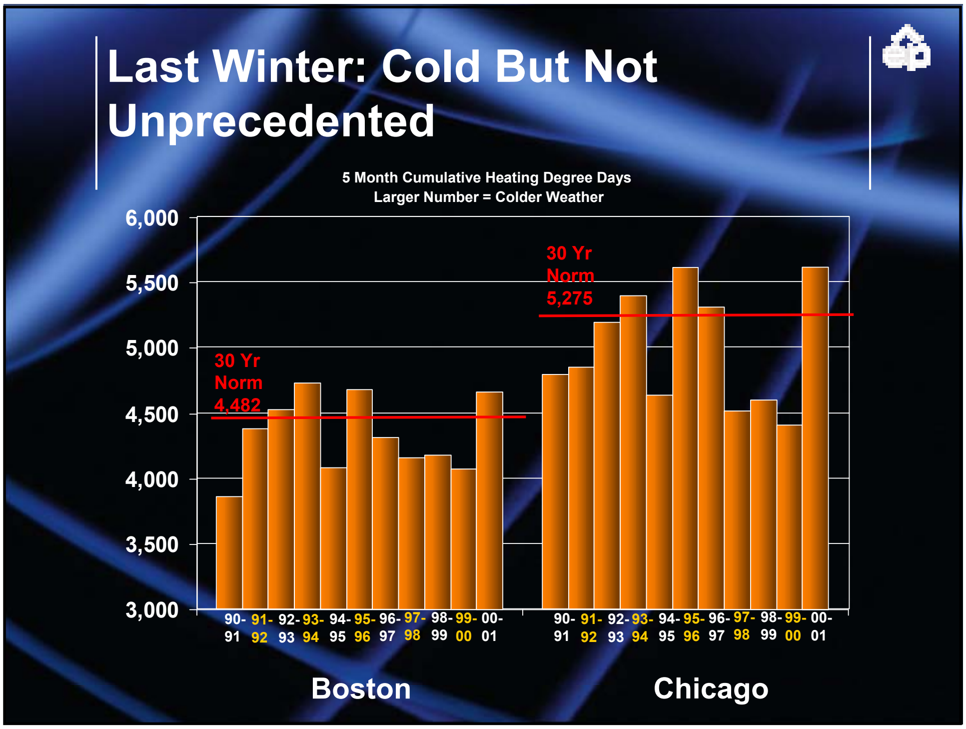
Vice President, Strategy and Capacity Pricing

Natural Gas Storage
R&D Workshop
November 29, 2001

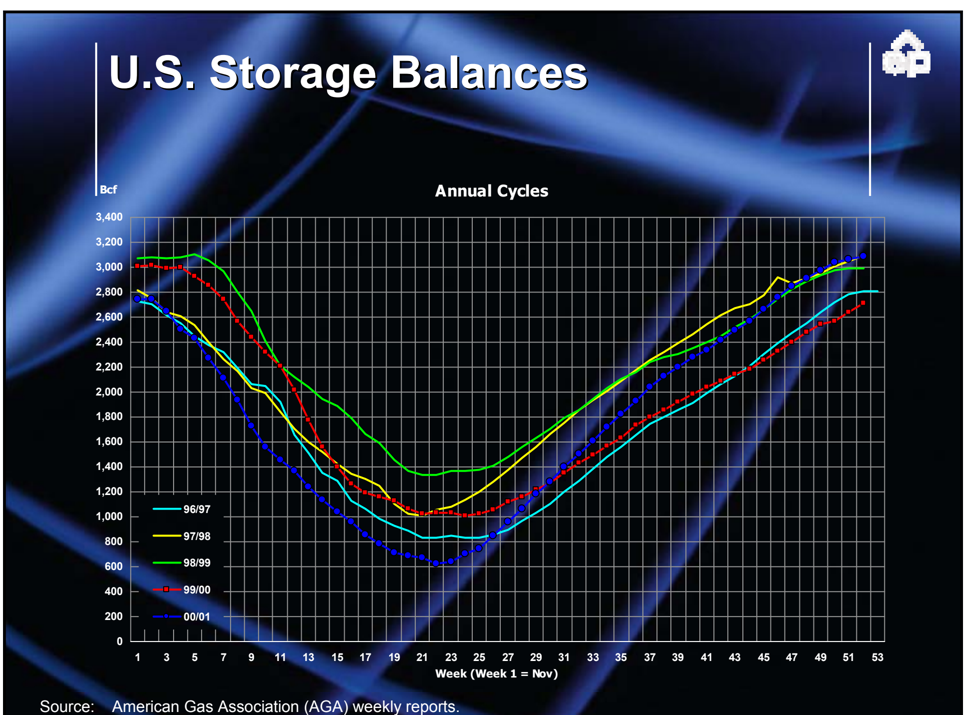
elpaso Pipeline Group

Agenda

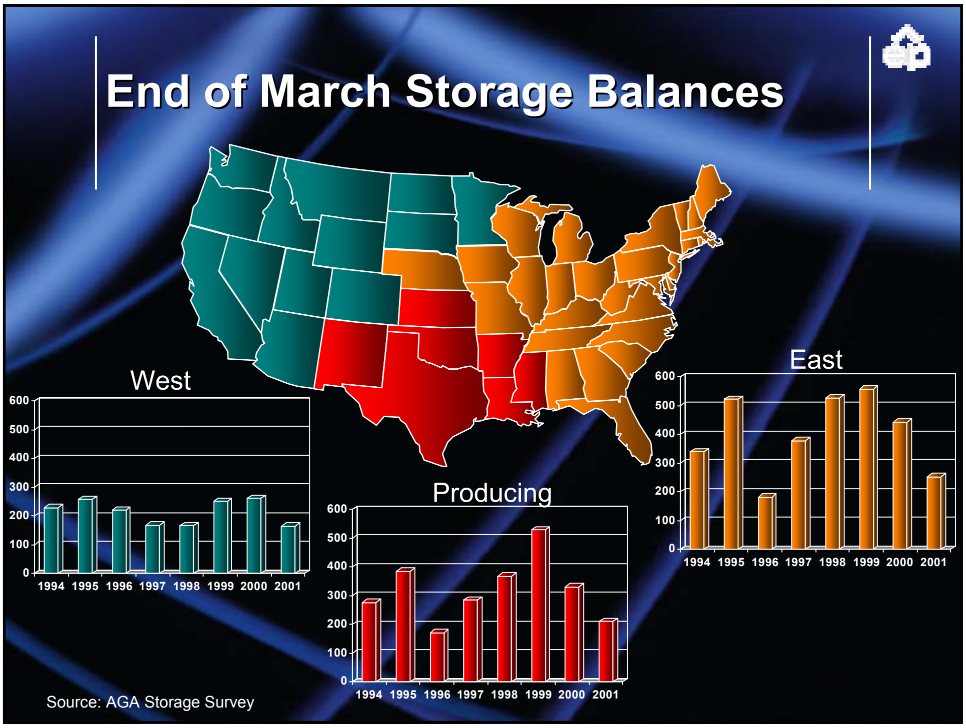
- 2000-2001 Winter
- Power Gen Demand vs. Storage Injection
- Changing Nature of Storage
- Regional Outlook
- Future Expansion
- Summary

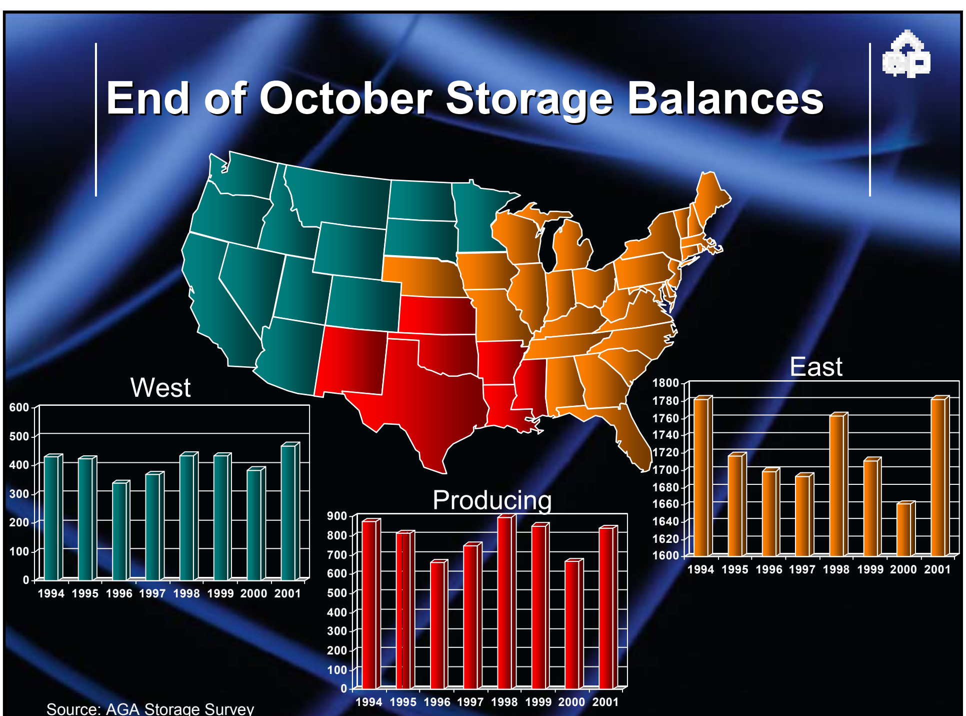


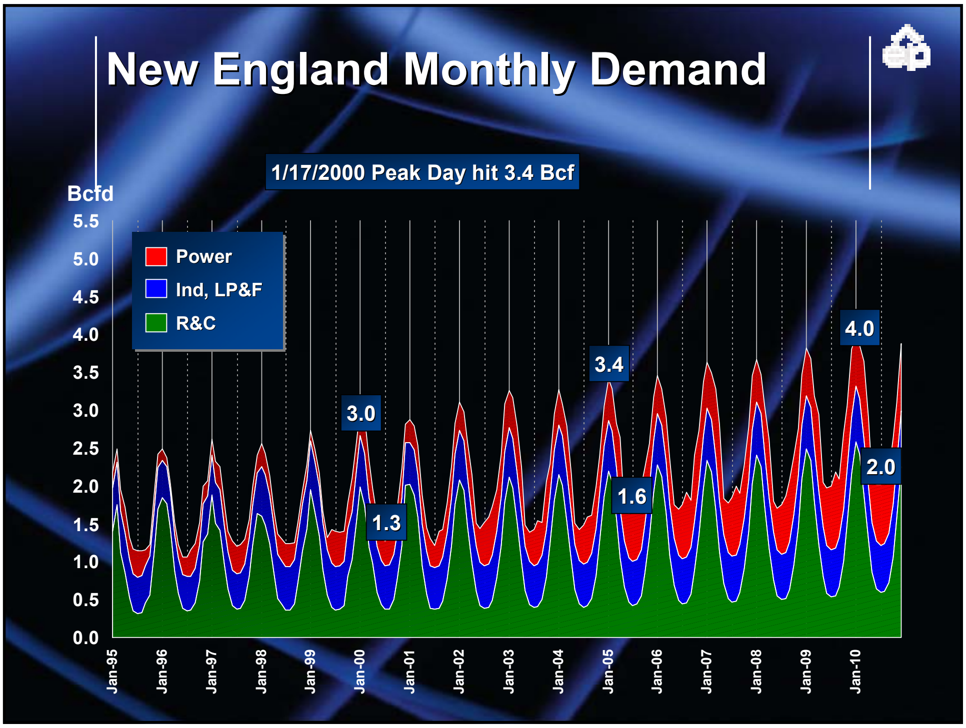
Last Winter: Cold But Not Unprecedented
5 Month Cumulative Heating Degree Days
Larger Number = Colder Weather
30 Yr Norm 5,275
30 Yr Norm 4,482
6,000
5,500
5,000
4,500
4,000
3,500
3,000
90-91 91-92 92-93 93-94 94-95 95-96 96-97 97-98 98-99 99-00 00-01
Boston
Chicago

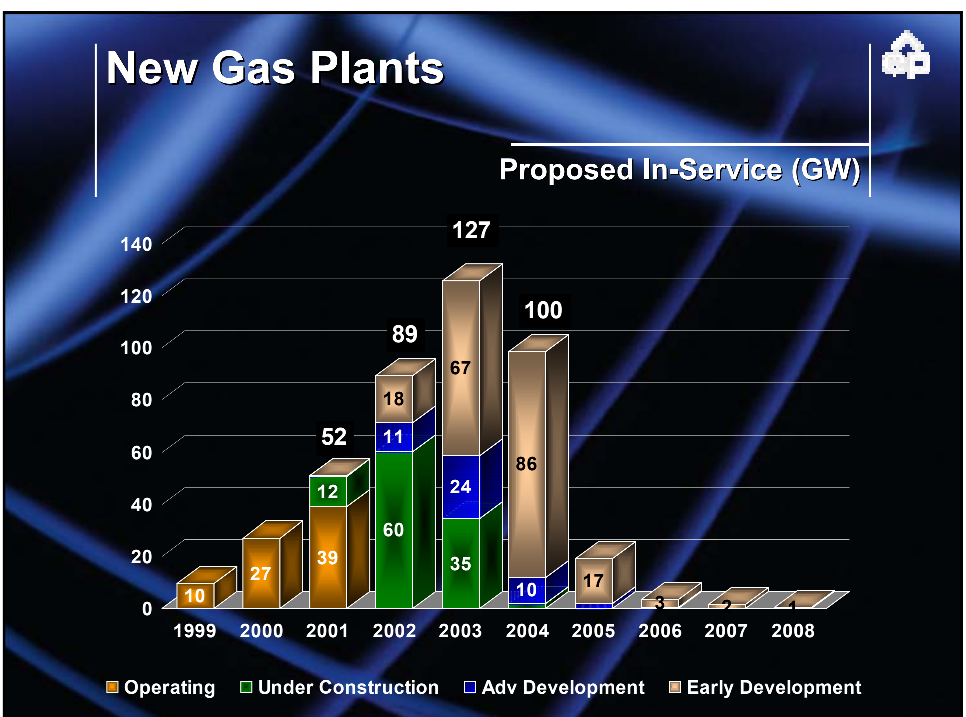


U.S. Storage Balances
Bcf
Annual Cycles
96/97
97/98
98/99
99/00
00/01
Week (Week 1 = Nov)
Source: American Gas Association (AGA) weekly reports.


End of March Storage Balances
West
600
500
400
300
200
100
0
1994 1995 1996 1997 1998 1999 2000 2001
Producing
600
500
400
300
200
100
0
1994 1995 1996 1997 1998 1999 2000 2001
East
600
500
400
300
200
100
0
1994 1995 1996 1997 1998 1999 2000 2001
Source: AGA Storage Survey


End of October Storage Balances
West
600
500
400
300
200
100
0
1994 1995 1996 1997 1998 1999 2000 2001
Producing
900
800
700
600
500
400
300
200
100
0
1994 1995 1996 1997 1998 1999 2000 2001
East
1800
1780
1760
1740
1720
1700
1680
1660
1640
1620
1600
1994 1995 1996 1997 1998 1999 2000 2001
Source: AGA Storage Survey

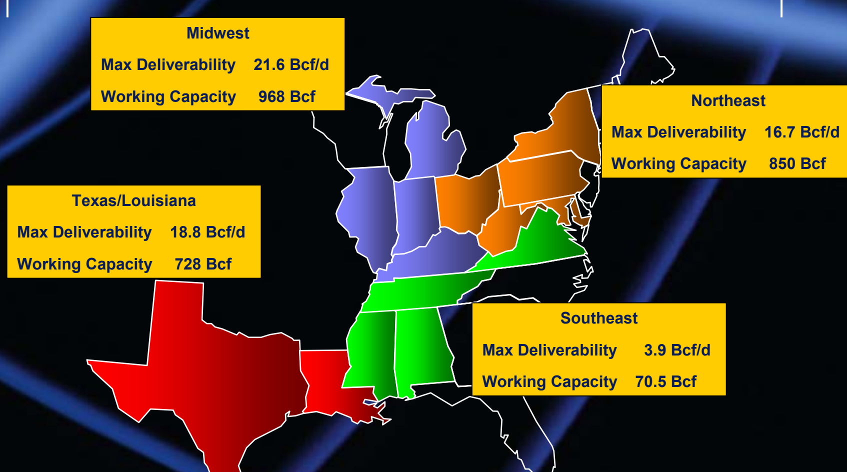

New England Monthly Demand
1/17/2000 Peak Day hit 3.4 Bcf
Bcfd
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Power
Ind, LP&F
R&C
3.0
1.3
3.4
1.6
4.0
2.0
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10


New Gas Plants
Proposed In-Service (GW)
140
120
100
80
60
40
20
0
10
27
39
12
52
60
11
18
89
35
24
67
127
10
86
100
17
3
2
1
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Operating
Under Construction
Adv Development
Early Development

Storage Product Dimension

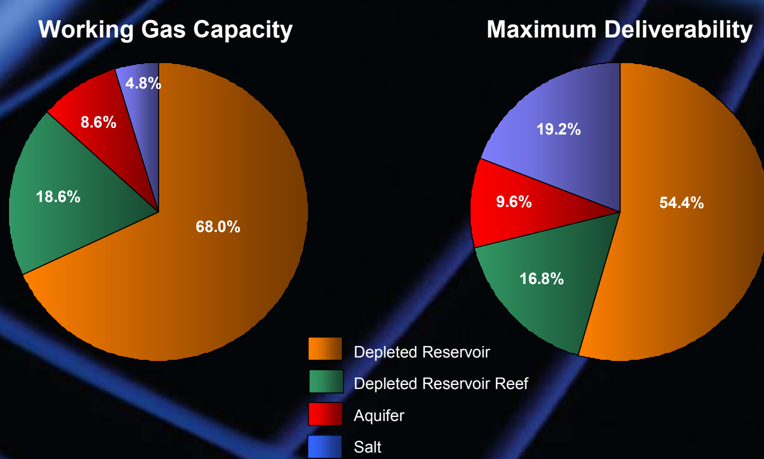
- Delivery Resource
- Transmission Surrogate
- Supply Insurance
- Seasonal Arbitrage
- Intra-seasonal Trading
- Trading Asset-Notional & Physical

Current Storage for Eastern US



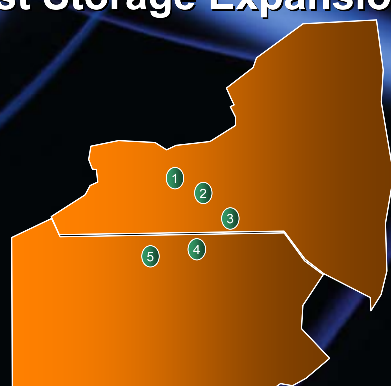
Source: International Gas Consulting

Geological Types of Storage: Eastern US/Southern Ontario



Source: International Gas Consulting

Northeast Storage Expansion Projects



		Working Capacity (Bcf)	Delivery Rate (MMcf/d)
1 Honeoye	Dep Reservoir	1.80	15
2 Seneca Lake II	Bedded Salt	.75	75
3 Stagecoach	Dep Reservoir	13.0	500
4 Tioga	Bedded Salt	6.0	500
5 Northeast ConneXion	Dep Reservoir	3.0	300

Source: International Gas Consulting / El Paso

Summary

- Growing demand and "normal" winters will test storage infrastructure
- Demands of fueling power generation could strain summertime storage refills
- Storage has evolved from a strictly physical asset to both a physical and trading asset
- Emphasis on gaining more flexibility from storage (along with supply and transport contracts)
- Changing flows and load patterns will lead to distributed deliverability solutions

elpaso

SECTION 3.0
Work Group Products

Following the plenary session presentations, the participants worked in three breakout groups, two for conventional gas storage and one for gas storage for power generation and remote off-pipeline. The three groups working in parallel identified:

- Key barriers to improved natural gas storage
- R&D opportunities/needs to overcome the barriers, and
- Implementation Strategy for priority R&D topics including component R&D activities and steps; capabilities, tools, facilities, and resources; collaborations, partners, and government role; geographic benefits; and impacts for deliverability and cycling, cost savings, safety and security, capacity, environment, and reliability.

Figure 1 provides an overview of the work group results. The detailed results follow.

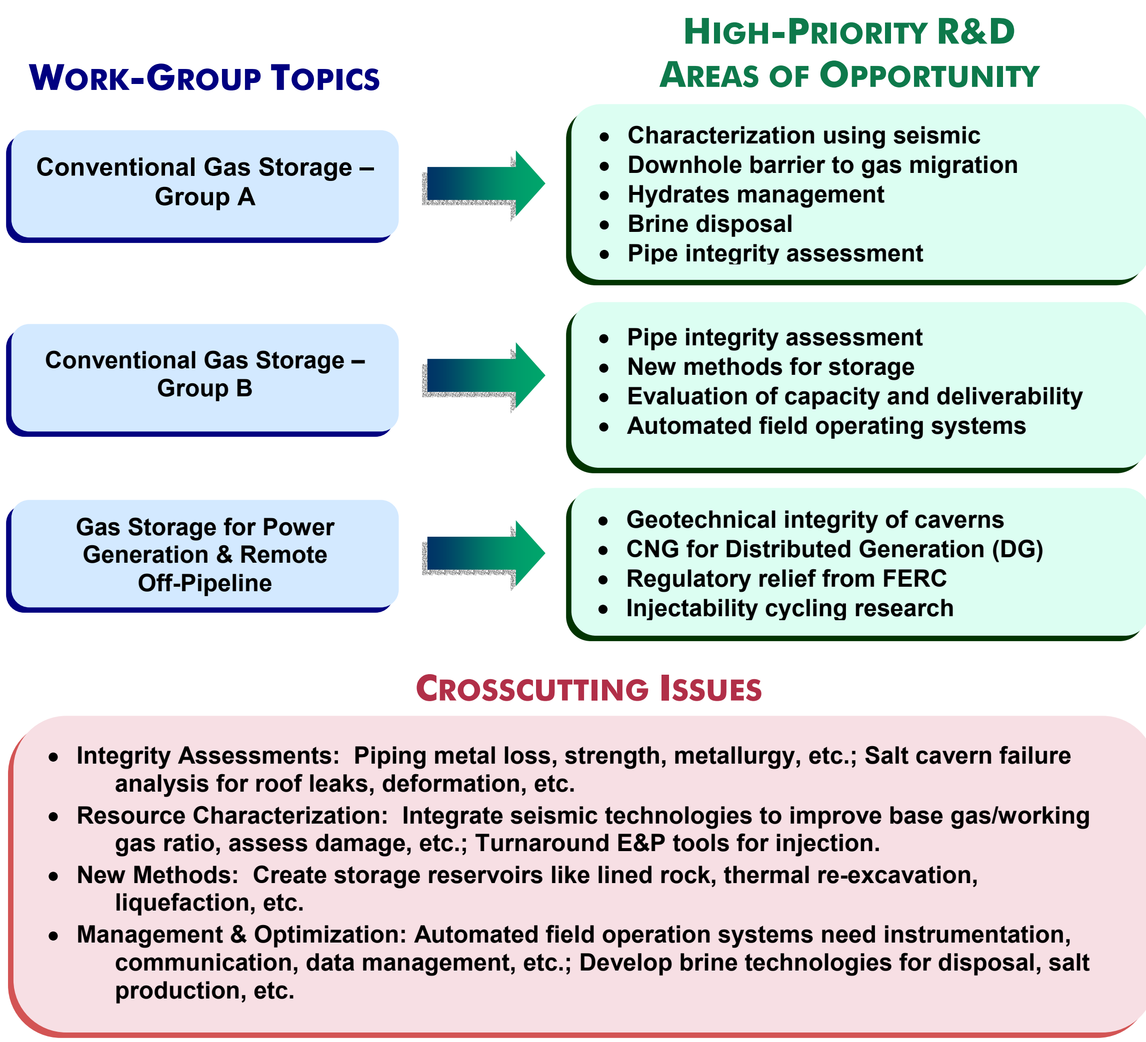


Figure 1. Overview of Gas Storage Workshop Results

3.1 Conventional Gas Storage – Group A

Reservoir characterization and management received the most focus. The former emphasized cheaper seismic or other methods to identify gas in-place, while the latter advanced barriers to gas migration and hydrates prevention. Both would have a maximum impact on capacity.

Participants: Conventional Gas Storage – Group A

Name	Organization
Nathan Anderson	El Paso Corporation
Steve Bauer	Sandia National Labs
Karen Benson	CMS Panhandle Companies
Ken Brown	Hoblitch Reservoir Technologies
Branko Damjanac	Itasca Consulting Group
John Finkbiner	Union Gas Limited
Steve Foh	Gas Technology Institute
Brian Hall	Equitrans, L.P.
Glenn Knepper	International Gas Consulting
Jim Mansdorfer	Southern California Company
Mike McCall	Conversion Gas Imports, LLC
Fred Metzger	DTE MichCon
Daopu Numbere	University of Missouri – Rolla
Joe Ratigan	PB-KBB, Inc.
Ken Squire	Halliburton Energy Services
Gary Sypolt	Dominion
Brad Tomer	DOE/NETL

*Report out presenter

Facilitator: Jack Eisenhauer, Energetics
Writer: Jennifer Cordero, Energetics

Technology Barriers

Barriers feedback from the group was easily categorized under seven major headings: reservoir characterization, damage at wellbore and injectivity, reservoir management, changing market conditions, salt/rock caverns, drilling technology, and integrity.

R&D Needs

The R&D needs to overcome barriers used all of the same topic headers from barriers except changing market conditions and added three new categories, gas processing, remote sensing and control, and other. Participants prioritized opportunity needs using one top vote and four regular votes. Under reservoir characterization, the need for seismic technology applications was the only one to receive four top votes. Two needs received a total of two top votes plus four regular votes: develop means of preventing/dealing with hydrates formed during operations and better means of assessing remaining strength (integrity). Another two needs received one top vote and four regular votes: develop a downhole barrier to gas migration and brine disposal. All of these opportunity needs were carried over to the implementation strategy for specific actions.

Actions

The group produced lists of activities for each of the top five priority opportunities, along with capability requirements, collaborations, geographic benefits, and a set of impact gauges. However, funding requirements were not ascertained. Collaborations generally will involve storage operators along with E&P and service companies. Government roles would be for funding and technology sharing, and geographic benefits would be widespread.

Conventional Gas Storage – Group A

Exhibit 3.1.1 Technology Barriers to Improved Natural Gas Storage

Reservoir Characterization	Damage at Wellbore and Injectivity	Reservoir Management	Changing Market Conditions	Salt/Rock Caverns	Drilling Technology	Integrity
Cheaper 3-D seismic Seismic or other technology to better identify gas filled porous bodies in reef structures Formation properties such as heterogeneities not well characterized Mechanical and hydrological characterization of rock mass Geological assessment of southeastern U.S. structures compatible with storage Low cost, 4-D seismic or other method to identify gas in-place at end of season Logging horizontal wells Differences in flow properties of gas during injection and production, i.e., hysteresis not well understood	Lack of chemical, minimally intrusive diagnostic techniques to accurately identify good stimulation candidates Determination of when/where damage occurs (injection vs. withdrawal vs both) Non-Darcy (i.e., turbulent) skin damage in high rate storage wells limits peak rates (turbulent flow in reservoir) Reduce cost of wellhead filtration Find best technology to best remove skin damage in wells Improve well injectivity Application of frac pac technology to thick, high permeability, unconsolidated sandstone reservoirs.	High levels of cushion gas to cycled gas Lower cost cushion gas replacement Quantify the pressure limits in a reservoir Improvement of working gas to base gas ratio in aquifers Low cost H_2S removal (Deliverability) – understanding gas hydrates Low cost, low O&M measurement and control technology for individual well pressure and flow measure, with oil, water, sand (+/- 10%); remote control Injection – Cycling required in future – Maintenance/supply Accurate assessment of full field potential to optimize working gas, feeding value, etc. Inventory verification – Accurate method – Little downtime – No time for shut-in	Strategically located underground space Injection season is too long Proper valuation of different storage services Conservative nature of LDC's – low tolerance of risk – high storage balances Transmission infrastructure into/out of new storage Limited research and expertise in transition from cryogenic to conventional storage Cost – No low hanging fruit – Deliverability needed – Volatility supports – At risk	Availability of cost-effective storage (salt, depleted reservoir) Effect of surrounding pressures on production from salt caverns Salt cavern brine disposal Lined rock caverns – Tunneling techniques	Greater use of multi-laterals: cost vs. short term benefits Horizontal drilling technology for hard rock reservoirs	Ability to make integrity decisions for aging infrastructure Determining gas loss and migration beyond dry hole perimeter Low cost, nonintrusive method of measuring downhole cathodic protection

CONVENTIONAL GAS STORAGE – GROUP A
Exhibit 3.1.2 R&D Needs to Overcome Barriers
Most Critical R&D Needs: ✪ = High Priority Vote ● = Priority Vote

Reservoir Characterization		Reservoir Management	Gas Processing	Damage at Wellbore and Injectivity	Remote Sensing and Control
Seismic technology applications — Working gas/Base gas ratio improvement — Accurate characterization using 3-D seismic simulator — Monitor reservoir — Illuminate periodically — Implement plan ✪✪✪✪ Develop alternative to surface seismic to identify by-passed gas — Minimize impact on community — Low cost/quick ✪●● Tie in real time pressure/rate data to build computer reservoir model ●● Better/lower cost cross-well seismic Research into techniques that enable seismic data to be reprocessed to identify reservoir characteristics Develop better numerical simulators to handle heterogeneities—hybrid FD/FE/BE simulators ●●	Development of process that combines geophysical in-situ and lab testing with proper models to characterize rock mass ● Laboratory study of permeability hysteresis for gas flow ● Test and analysis progress to deformation near wellbore coupled mechanical/fluid deformation short/long term ● Understanding of transition between continuum – discontinuum response of rock mass time and length-scale ● Develop cheaper rotary sidewall coring tool that reliably operates in air and in hard rock without overheating (and in cased hole) ● Research/fabrication/ testing of smaller more flexible logging tools for use in horizontal well bores ● Application of ground penetrating radar	Reversible downhole barrier to gas migration (foam, polymers) ✪●●●● Explore using reservoir limits test technologies to replace S/I's for inventory monitoring ●●●●● Remote sensing of migrated gas ●●●● Computer model to accurately predict inventory—no shut-in required ● Study dual-use of storage—liquid and gas, seasonal?	Develop means of preventing/dealing with hydrates formed during operations ✪✪●●●● Reduce cost of wellhead filtration ●●●●● Better final cleaning procedure for the injecting steam—electrostatic? Or any other ● Designing and testing of hydrogen removal equipment geared to smaller storage operations Reduce cost of compression	Sampler or recorder to determine type and extent of wellbore damage ✪✪ Develop testing methods for skin damage determination in caverns as opposed to wells (caverns and wells) ●●● Prevention of damage — Recommendation/ best practice already in existence — Study for damage issues not dealt with by best practices/economics ●●● Prevent deliverability loss due to water encroachment (relatively permanent damage) ●●	Electronic flow measurement – non-intrusive rate measuring device that does not require extensive facilities and can handle multiple phases ✪✪● Downhole pressure measurement-develop wireless communication technology that requires minimal energy so downhole sensors can communicate with surface recorders over extended periods (months, years) ●●● Electronic flow measurement-communication -cheaper, more reliable communication technology that does not require line-of-sight for communication ● Less expensive instrumentation/ control equipment for reservoir management

Conventional Gas Storage – Group A

Exhibit 3.1.2. R&D Needs to Overcome Barriers *(continued)*

Most Critical R&D Needs: ✪ = With Major R&D Component ● = With Minimal R&D Component

Salt/Rock Caverns	Integrity	Drilling Technology	Other
Proof of concept scale test heat transfer of LNG to brine ✪●●●● Develop new salt production (from brine) technologies ●● Research tunneling in other countries ● Alternative method to remove salt for cavern formation—heat? Develop brine concentration method to reduce injection volume (inexpensive)	Better means of assessing remaining strength. Better means of measuring metal loss. ✪✪●●●● Device to measure current flow downhole. Application of pipeline current mapping device ●	Reduce cost of drilling workovers – Lasers? – Conventional ●●● Horizontal drilling in hard rock Directional hammer bit with	Expedited processing of governmental approvals for pipeline expansions Promotion of frontier supply areas (and improved drilling techniques) to provide adequate supply for injection.

Conventional Gas Storage – Group A
Exhibit 3.1.3. Implementation Strategy

R&D Priority	Component R&D Activities and Steps	Capabilities, Tools, Facilities, and Resources	Collaborations, Partners, Government Role	Geographic Benefits	Impact (0-5)
Use seismic and alternative technologies for better reservoir characterization and monitoring for better working gas to base gas ratio	Develop full cycle model Benchmark/Baseline review Hardware development Software development Research on more controllable seismic sources Improve resolution Tailor to natural gas storage needs Build simulator Integrate current industry technologies to attack problem Non-surface seismic=>alternative, non-invasive	Candidate reservoir Geophysicists Modeling expertise Remote sensing capabilities	Universities => interpretation Industry: storage (data) Geophysical companies Oil/E&P companies Military expertise (national/defense labs) Government Role – Funding – Technology sharing	Widespread Largest: areas w/ existing reservoirs and some new	Deliverablity/Cycling = 3.5 Cost Savings = 4.5 Safety and Security = 1 Capacity = 5 Environmental = 1.5 Reliability = 3
Develop a downhole barrier to gas migration	Study barrier placement Location criteria Material/chemical studies Accurate reservoir characterization Monitoring techniques	Physical chemistry expertise Lab testing Test reservoir	Storage operating company Academia Well service companies Chemical companies Waste remediation companies Government Role – Funding – Apply waste experience (technology sharing)	Widespread Especially aquifer operations	Deliverablity/Cycling = 2 Cost Savings = 3.5 Safety and Security = 3 Capacity = 5 Environmental = 3 Reliability =3

CONVENTIONAL GAS STORAGE – GROUP A
Exhibit 3.1.3 Implementation Strategy *(continued)*

R&D Priority	Component R&D Activities and Steps	Capabilities, Tools, Facilities, and Resources	Collaborations, Partners, Government Role	Geographic Benefits	Impact (0-5)
Develop a method to prevent/handle hydrates formed during operations	Basic chemistry & thermodynamic studies Computational flow/fluid dynamics Sensing technologies Phase behavior	Basic chemistry Lab test facilities Flow loop Field test	CFD consortium Chemical companies Academia/universities Storage field operator Government Role – Funding – Technology sharing	Especially cold climates High pressure reservoirs	Deliverablity/Cycling = 2.5 Cost Savings = 3 Safety and Security = 3.5 Capacity = 0 Environmental = 0 Reliability = 5
Develop brine disposal method	Disposal studies Alternative uses/by-products Small volume salt production Geologic studies Technology adoption/transfer	New salt production technology Geologic studies Geologic characterization Reservoir characterization	Salt industry Gas storage operators Liquid storage operators Oil producers Government Role – Funding – Government regulatory cooperation – Incentives – Facilitator	Northeast (W. NY, W. PA) Michigan Central AZ	Deliverablity/Cycling = 4 Cost Savings = 5 Safety and Security = 0 Capacity = 2 Environmental = 2 Reliability = 0
Develop method to better assess metal loss and remaining strength	Look at line pipe studies Process piping thickness surveys Metallurgy studies Gather info/data from operators that have done studies Burst testing	Correlation modification to fit downhole pipes Lab to perform burst test	Storage field operator Well service companies Corporate/industry labs Universities National labs Regulatory assistance Collaboration with national labs Funding Objective evaluation of cap.	Widespread	Deliverablity/Cycling = 1 Cost Savings = 4 Safety and Security = 4.5 Capacity = 0 Environmental = 4.5 Reliability = 4

3.2 Conventional Gas Storage – Group B

This group was charged to address research needs in the area of conventional natural gas storage. The group accomplished this by creating the following three products:

- Barriers to improve conventional natural gas storage,
- Research and development needs and opportunities to overcome the barriers, and
- Implementation strategies for the highest priority research and development needs.

The group's composition was well balanced by managerial and technical representatives from industry, government, and universities. Support for the group diversity was noted; generally contacts are only made among individuals in similar positions. A positive synergy developed as not only products were developed, but information was also exchanged. This "educating" of the group assisted in brainstorming. Once everyone had an understanding of major topic areas, ideas flowed more smoothly.

Participants:
Conventional Gas Storage – Group B

Name	Organization
Steve Bergin	ONEOK
Jim Blasingame	Dominion Transmission
Bob Bretz	New Mexico Tech
Ryan Connors	Equitable Utilities
Rick Daniel	Alberta Energy Company
Joe Frantz	Hoblitch-Reservoir Technologies
Rick Gentges	El Paso Corporation
Mark Gredell*	Duke Energy North America
John Guoynes	Halliburton Energy
Paul Harris	GDF Energy, Inc.
Will Johnson	Visage Energy Group
Shahab Mohaghegh	Intelligent Solutions, Inc.
Thomas Mroz	NETL
Larry Myer	LBNL
Larry Pekot	Advanced Resources International
Gary Sames	NETL

*Report out presenter

Facilitator: Alicia Dalton, Energetics
Writer: Josh Chaddock, Energetics

The first brainstorming session focused on the barriers to improve conventional natural gas storage. Then the group organized the barriers into the following categories: Reservoir Characterization, Market Uncertainty/Risk, Integrity, Existing Facilities, Regulations, and Other. The complete results for this product are given in Exhibit 3.2.1.

The group then brainstormed on research and development needs and opportunities to overcome the barriers to improve conventional natural gas storage. Again, the group organized the needs into categories: Education and Technology Transfer, Existing Facility Optimization, Regulation, Reservoir Characterization, and New Technologies. The group was given the opportunity to vote using one highest priority vote and four general votes. Based on group consensus, the highest priority needs would become the basis for implementation strategies to be detailed by the participants. The group also arranged the needs into time frames based on when the impacts of the accomplishment of the need would be felt by the industry: Short Term (0 – 5 years), Mid-Term (5 – 10 years), and Long-Term (10 – 15 years). The complete results of this product can be found in Exhibit 3.2.2. The following four research and development needs were the top vote-getter topics and thus formed the basis for the implementation strategies:

- Integrity: Develop advanced casing inspection tools capable of characterizing pipe condition,
- Develop new methods for creating storage reservoirs,
- Evaluate current reservoir capacity and deliverability, and
- Automated field operating systems.

For each topic, the group identified component research and development activities and steps; capabilities, tools, facilities, and resources; collaborations, partners, and the government's role; and geographical benefits. The participants also reached consensus on the impact level that each priority need could have on a given set of factors: develiverability/cycling, cost savings, safety and security, capacity, environmental, and reliability. Scores for impact were given from zero to five, corresponding to no impact to the utmost impact, respectively. The implementation strategies can be viewed in their entirety in Exhibit 3.2.3.

During brainstorming, many new ideas were generated, out of the box thinking occurred, and group consensus was reached. But several ideas and discussions surfaced that may not be completely represented in the products.

- Throughout the day, the group stressed the problems associated with the "legacy" of regulation and that it proved to be quite a hindrance for natural gas storage. Since a focus of this particular workshop was research and development opportunities, little could be done in the area of regulations, but the group did want to stress its importance.
- Questions were raised about the government's role and who should effectively take the lead in many of the implementation strategies. Overall, it was determined that the government successfully has functioned as a facilitator hosting workshops to bring together diverse groups of storage professions, and that such a role should continue. The participants also noted that the government could be instrumental in funding and technology transfer.
- Several participants had views regarding aquifer storage versus other means of conventional gas storage. The support for aquifer use was not felt as strongly by industry as by academia in this particular session.

Although "Develop new methods for creating storage reservoirs" received the second highest priority ranking, during the implementation strategy it was discovered that little impact on the industry would result from its success. No impact score higher than 2.5 was given in the implementation strategy (see Exhibit 3.2.3). A discussion ensued resulting in a group consensus that although the need received significant votes, its impact on conventional natural gas storage would be minimal.

CONVENTIONAL GAS STORAGE – GROUP B
Exhibit 3.2.1 What are the Barriers to Improve Conventional Gas Storage?

Reservoir Characterization	Market Uncertainty/ Risk	Integrity	Existing Facilities	Regulations	Other
Extending peaking ability from conventional reservoirs Some converted wells are not properly spaced; optimum well spacing Lack of production methodology for water/gas flow in aquifer storage Need better brine disposal Lack of method of brine water disposal for salt projects Need for information and analysis quicker; data availability Need to get expertise in reservoir model in right hands Lack of reservoir characterization What is real reservoir capable of performing? Lack of integrated geologic, reservoir, and performance data Coupled reservoir simulation, i.e., reservoir, wellbore pipeline, facilities Lack of suitable reservoirs (new reservoirs) Lack of quality data Damaged reservoirs (wells)	Geographical locations of suitable reservoirs Limited in new projects by available quality depleted gas reservoirs Some technology options are high risk Market uncertainty Difficulty valuing existing regulated assets Cushion gas cost	Lack of methodology to accurately (and economically) measure stress (delta-pressure)	Strength of materials and regulatory limits on safe operations practices Need models for entire system No strength of materials models for existing wells Age of existing facilities—limits the options available to re-engineer asset Aging infrastructure originally designed for seasonal service Surface and pipeline constraints Pipeline capacity from storage "island" to the market Lack of flexibility of field/well operations	The legacy of regulation Regulatory uncertainty Utilities lack incentives Lack of regulatory clarity for shifting assets out of regulation Reservoir pressure limitations—limited in most states by discovery pressure	Concise collaborative technology initiative Limited technical manpower talent Technology not up with the times Lack of technology man hours (for simulation) Technology transfer

CONVENTIONAL GAS STORAGE – GROUP B

Exhibit 3.2.2 What are the R&D Opportunities/Needs to Overcome the Barriers?

Most Critical R&D Needs: ✪ = High Priority Vote ● = Priority Vote

Timeframe	Education and Technology Transfer	Existing Facility Optimization	Regulation	Reservoir Characterization	New Technologies
SHORT-TERM (0-5 YEARS)	Other - encourage/ foster closer government/industry technology research initiative ●●●●● Educate U.S. consumer, business, government, and financial world on storage industry, regulations, and barriers DOE to act as liaison with regulators to reinforce industry opinions on the safety of underground gas storage practices DOE to continue to serve as collaborative technology forum to bring storage operators together with research initiatives	Automated field operating systems ●●●●●●●● Research into geo-mechanical predictive mechanisms in conventional gas storage reservoirs ✪●● Identify the right data to collect (identify performance drivers) ●●● Reengineering of baseload fields for higher value services ●●● Develop technologies that allow for re-entry into existing well bore for recompletion in a better quality area of reservoir ●● Develop cost-effective method to produce gas/water in aquifer storage	Storage industry task force on deregulation ●●● Perform risk assessment analysis EH&S ●●	Better coupled reservoir/surface simulators ●●●●●● Evaluate current reservoir capacity and deliverability ✪✪✪ Permanent geophysical monitoring ✪●●● Integrated geophysics and reservoir modeling ●● Develop simple, quick, integrated data analysis methods ● Develop cost-effective data collection strategy ●	Integrity: Develop advanced casing inspection tools capable of characterizing pipe condition ✪✪✪✪● Develop new methods for creating storage reservoirs ✪✪✪● Market Uncertainty/ Risk: Develop tools/products to evaluate base gas alternatives (lower cost) ●●●● – Use of inert cushion gas Integrity: Develop methods to accurately calculate stress from existing logs ✪ Research suitability of unconventional reservoirs (i.e., deep, fractured) ● Improved data management system ● Develop new technology to assist engineers and managers make better decisions – Lined rock cavern for areas with no salt or reservoir Improve methods for inventory verification
MID-TERM (5-10 YEARS)			Redesign regulatory framework ●●	Permanent geophysical monitoring ✪●●●	Utilize hydrates as storage medium
LONG-TERM (10-15 YEARS)					New methods for brine disposal and use ●

CONVENTIONAL GAS STORAGE – GROUP B
Exhibit 3.2.3 Implementation Strategy

R&D Priority	Component R&D Activities and Steps	Capabilities, Tools, Facilities, and Resources	Collaborations, Partners, Government Role	Geographic Benefits	Impact (0-5)
#1 Integrity: Develop advanced casing inspection tools capable of characterizing pipe condition	Evaluation of current tools Evaluation of integrity of multi-concentric strings Further development of current tasks Design parameter characterization Develop correlations between log interpretations to strength of materials to determine wellbore integrity	Oil Field Service Co—have ability to do tool research Southwest Research Battelle Gaz de France	Service companies (Tool development lead) Operators (lead) Laboratories (lead) University American Petroleum Institute Interstate Oil & Gas Compact Commission (IOGCC) ASME SPE – Society of Petroleum Engineers Collaboration Types – Joint research ventures – Committees Government Role – Organize – $ – Technology transfers – Facilitate	Everywhere	Deliverablity/Cycling = 4 Cost Savings = 4 Safety and Security = 5 Capacity = 0 Environmental = 4.5 Reliability = 4

CONVENTIONAL GAS STORAGE – GROUP B

Exhibit 3.2.3 Implementation Strategy *(continued)*

R&D Priority	Component R&D Activities and Steps	Capabilities, Tools, Facilities, and Resources	Collaborations, Partners, Government Role	Geographic Benefits	Impact (0-5)
#2 Develop new methods for creating storage reservoirs	Continue work on lined rock caverns Regional geologic feasibility cost benefit studies Thermal re-excavation New aquifer methods New sealing methods Cost reduction (liquefaction) Abandoned coal mines Higher Btu content	National Labs Geological societies (USGS) Universities AAPG Service companies DOD drilling techniques ARMA A&E Co. API for Btu	USGS State geological societies University Service companies Operating companies Construction companies Joint research ventures Conservation Joint business ventures State agencies Government Role – $ – Research – Coordination – Technology transfer Government leads with USGS	New England Mid-Atlantic South East Creates a new "everywhere"	Deliverablity/Cycling = 1 Cost Savings = 1 Safety and Security = 0 Capacity = 1 Environmental = 1 Reliability = 2.5
#3 Evaluate current reservoir capacity and deliverability	Quantify effect of damage on deliverablity Impacts of lost gas Identify source of damage Geomechanical integrity Optimize reservoir performance Advanced data interpretation Update/advance reservoir characterization	Service companies Universities Consultants Operators National Labs Tool well test analysis Geologic reservoir models Reservoir simulation Artificial intelligence Methods of advanced data collection	DOE Private industry Operators Consultants Universities Labs Government Role – None? – $ – Coordination – Technology transfer	Everywhere (new and old)	Deliverablity/Cycling = 5 Cost Savings = 5 Safety and Security = 1.5 Capacity = 5 Environmental = 3 Reliability =5

CONVENTIONAL GAS STORAGE – GROUP B
Exhibit 3.2.3 Implementation Strategy *(continued)*

R&D Priority	Component R&D Activities and Steps	Capabilities, Tools, Facilities, and Resources	Collaborations, Partners, Government Role	Geographic Benefits	Impact (0-5)
#4 Automated field operating systems	Survey existing practices Cost effective instrumentation Communication technology Data storage/management Data integration Data mining and analysis Artificial intelligence Scope = include pipeline to reservoir Maintenance and reliability of existing systems	Service companies Implementation firms Software data developers Industry Process control Communication companies Demonstration sites	Industry Service companies Operators Consultants Universities Labs Software companies Instrumentation people Collaboration Types – Develop technology – Collaborative/Cooperative agreements Government Role – Technology transfer – Coordination – $	Everywhere	Deliverablity/Cycling = 3 Cost Savings = 4 Safety and Security = 5 Capacity = 0.5 Environmental = 2 Reliability = 5

3.3 GAS STORAGE FOR POWER GENERATION & REMOTE OFF-PIPELINE

Participants:
Gas Storage for Power Generation & Remote Off-Pipeline

NAME	ORGANIZATION
Jim Ammer	DOE/NETL
Ken Beckman	International Gas Consulting, Inc.
George Bonner	Energy East Enterprises
Paul Britton	EnerSea Transport LLC
Charles Chabannes	Duke Energy
Dean Cockshutt	Alberta Energy Company
Kerry DeVries	RESPEC
Don Duttlinger	PTTC
Baba Fapohunda	SAIC
Bill Fay	Westcoast Energy Inc.
Edmund Knolle	Falcon Gas Storage
John Martin	NYSERDA
Noah J. Matthews	Representing Schlumberger (Private Consultant)
Joel Nieland	RESPEC
Tom Siguaw*	MHP/Acres Management Consulting
Chuck White	EnerSea Transport
David Williams	Williams Energy Services
Al Yost	DOE/NETL

*Report out presenter

FACILITATOR: Kevin Moore, Energetics
WRITER: David Iorio, Energetics

Projections of future storage needs and increased gas consumption targets were of little value to the group. The only salient points were the need for high deliverability and new storage locations and options like CNG. Most important was the fact that injectability is the primary concern, more so than deliverability. Nearly all R&D would be for a near-term 0-5 year time horizon. There was a consensus to use existing E&P techniques by turning them around for injectability. Given the importance of salt caverns for deliverability, a top priority is to monitor and analyze their long-term integrity. By examining case studies of failures, design improvements can be made on the front end of construction. Another priority is the need to somehow get the Federal Energy Regulatory Commission (FERC) to grant regulator relief to storage aspects, especially for expansion at utility storage sites.

The ability to use an existing storage well for observations, experimentation, and verification is very cheap compared to drilling a new well and should be pursued. Moreover, the risk of failure for new storage wells cannot be absorbed and is deterring investment. Another costly aspect is the compression requirement for additional gas in salt mines. LNG is also expensive, and on-site liquefaction is not fast enough for power delivery. So, the economic benefits to power consumers from enhanced storage infrastructure should be modeled, optimized, demonstrated, and publicly reported.

BARRIERS AND ISSUES

Barriers feedback from the group was easily categorized under five major headings: injectability cycling, regulatory, capital risk, remoteness and location, and technical risk. Injectability is a larger problem than deliverability, especially for conventional storage in the Rocky Mountains and the Northeast. Some of the easiest engineering expansion projects for utilities cannot be done because of regulatory barriers. Capital risk issues stem from the lack of any rate base spreading and liquidity during high demand; the market mechanisms are just not there. Brine disposal is a prevalent inland problem away from seashores.

OPPORTUNITIES

The R&D opportunities used the same topic headers from barriers, and added an environmental restriction category. Participants prioritized opportunity needs using one top vote and four regular votes. Under technical risk, the need for long-term integrity of bedded salt caverns information was the only one to receive three top votes. Two other needs received a total of 6 votes: FERC 7C relief and CNG solutions. Another two needs received two top votes and two regular votes: reservoir engineering and economic benefit. All of these opportunity needs were carried over to the implementation analysis.

Time frames for most of the topics were short-term. Cogeneration and distributed generation needs were assessed to be mid-term given the current market. Only the inert gas need was long-term, and it appears that European endeavors are currently addressing this issue. The group did have the foresight to change exotic to novel for R&D needs.

ACTIONS

The group produced lists of activities for each of the top 5 priority opportunities, along with capability requirements, collaborations, geographic benefits, and a set of impact gauges. However, funding requirements were not ascertained. There was a strong emphasis on using existing E&P tools to apply to storage problems by reversing the focus from production to storage. In other words, how can we use the technological advances in E&P to apply to injectability and cycling issues? A technology angle for FERC regulatory relief is imperative to meet NETL R&D requirements.

Collaborations generally will involve storage operator along with E&P and service companies. Government roles in general would be regulatory with involvement for the Environmental Protection Agency and State regulators. Geographic benefits would accrue to anywhere and everywhere there is storage for the most part. CNG solutions would benefit downtown coastal urban areas, and would allow the system to be pressurized from ends to effectively increase capacity.

Impacts gauges oscillated between nearly none to maximum impact. None of the categories was always high or low, though the reliability category was relatively high with an average of four for impact. Conversely, safety and security were for the most part low impacts except for the long-term geotechnical integrity of bedded salt caverns. Cost savings impacts were in the 3 –3.5 range except for CNG solutions.

Gas Storage for Power Generation & Remote Off-Pipeline

Exhibit 3.3.1 What are the Barriers to Improve Gas Storage for Power and Remote Off-Pipeline?

Injectability Cycling	Regulatory	Capital Risk	Remoteness and Location	Technical Risk
Injectability larger problem than deliverability especially conventional storage reservoirs — Especially Rocky Mountain and northeast Pad gas and working gas — Reduce ratio — Inert gas — Recovery Storage gas cycling for delivery to power generating facilities/gas injection Flexibility—injection/withdrawal at short notice—controls Counter cycling service/reservoir inventory management Reliability The storage needs for peakers different from baseload plants Downstream deliverability of available capacity Balancing power peak requirements with upsets “nominations”	Barrier, no regulatory incentive! — Easiest projects cannot be done — Especially utilities with basic engineering Air emission limitations limits injection compressor emissions Pipeline use: — Cost allocation — Industries subsidize IPP’s, LDC’s Delta pressuring to increase working capacity—regulatory restrictions Public acceptance “NIMBY,” regulatory impediment Relative environmental impact (CO_2)	Regulatory – capital risk allocation – independent merchant has no rate base to absorb mistakes Reservoir evaluation – staging risk Risk market will overbuild due to regulatory impediments Market liquidity during high demand periods – “it is not available”	Remoteness itself is a barrier. It is economic risk. Security vs. terrorism sensitivity of storage medium Good DG sites usually off-pipeline	Salt cavern brine disposal Geologically constrained areas “no or low deliverability” Resource conservation/loss (shrinkage) Is there a role for onsite LNG storage at power plants? Regulatory, technology, economic barriers — Trucking and liquefaction on site Personnel — Training — Experience — Education — Commercial savvy

GAS STORAGE FOR POWER GENERATION & REMOTE OFF-PIPELINE

Exhibit 3.3.2 What are the R&D Opportunities/Needs to Overcome the Barriers?

Most Critical R&D Needs: ✪ = High Priority Vote ● = Priority Vote

Timeframe	Injectability Cycling	Regulatory	Capital Risk	Technical Risk	Remoteness and Location	Environmental Restrictions
NEAR-TERM (0-5 YEARS)	Research into well completions, fracturing, reservoir engineering, better simulation techniques ✪✪●● Research into better control mechanisms to enhance flexibility ✪ Alliance with engine/compressor manufacturers for cycling units ● Non-damaging compressor lubricants	Expedited or elimination of FERC 7C relative to risk ✪✪●●●● Economic benefit to power consumers with enhanced storage infrastructure ✪✪●● National asset reevaluation ●● R&D can show magnitude of the engineering opportunity ● Downhole safety valves "screwed" ● Electric Motor Drive (EMD) at storage exempt from power curtailments on interruptible (IT) contracts Research into improved operational efficiency and technologies that preserve national resources	Commercial optimization ●●●	Long-term integrity of bedded salt caverns information ✪✪✪● Cement quality, bond quality, pipe quality ●●● – Longevity/safety casing and wellbore design Brine disposal alternatives and opportunities – increase saturations during leeching ●● LNG vaporization technology Focus especially operations/tools to storage development	CNG and other solutions ✪●●●●● Better ways to look inside salt ●●●● Facility safety/security report ● Distributed generation vs. central station infrastructure requirements R&D	Compressor environmental performance Risk of SCR application to gas storage
MID-TERM (5-10 YEARS)	Variable speed compressor ●●		Other value added solutions, e.g., cogeneration ●● Better and cheaper reservoir modeling	Gas cleanup for H_2O/CO_2 in LNG process and gas liquids	Novel R&D ✪●● New, tools for cheap screening new formation ●● Distributed Generation R&D must include storage options ●● Assessment of underground reservoir traps	Gas migration assessment and abandonment ●●
LONG-TERM (10-15 YEARS)				Use of inert gas for PAD gas ●●●		

Gas Storage for Power Generation & Remote Off-Pipeline

Exhibit 3.3.3 Implementation Strategy

R&D Priority	Component R&D Activities and Steps	Capabilities, Tools, Facilities, and Resources	Collaborations, Partners, Government Role	Geographic Benefits	Impact (0-5)
#1 Long-term geotechnical integrity of bedded salt caverns, e.g., roof leaks, deformation	Geologic analysis Failure analysis and definition Monitoring feedback for better front end	Casing design E&P tool, lab tests, database raise it to a safety issue	Among industry SMRI, GTI, DOE/SPR, NYSERDA, academia, government-public meetings	Appalachia, Canada, Central Mid-West, Northern Mexico	Deliverablity/Cycling = 1.5 Cost Savings = 3 Safety and Security = 5 Capacity = 5 Environmental = 4 Reliability = 5
#2 CNG and other solutions, remote application needle peak, DG support	Demonstration Marketing feasibility study Regulatory support Security aspect education	Equip designers, end-users, pilot plant	Storage developer and power generator and end user industry Government-regulatory standards and funding	Anywhere in rural and urban downtown Double pipeline capacity downtown and coastal urban – Feed both ends of loop	Deliverablity/Cycling = 5 Cost Savings = 1 Safety and Security = 2 Capacity = 1 Environmental = 4.5 Reliability = 5
#3 Expedited or elimination of FERC 7C relative to risk	Independent study Experimental well by the operator/risk taker Assessment of opportunity and risk	Education and workshop E&P tools Active role by service companies	E&P and service companies and storage operator State government, EPA	Everywhere. Good for salt and reservoir	Deliverablity/Cycling = 4.5 Cost Savings = 3.5 Safety and Security = 2 Capacity = 5 Environmental = 1 Reliability = 4
#4 Research into well completions, fracturing, reservoir engineering, better simulation techniques for injectivity timing	Apply E&P tools to study going other way for injection. Focus on storage vs. production. Reservoir engineering model	Use existing field for pilot studies Reservoir engineering model match	Storage operators and service and E&P State regulators, and EPA	Anywhere reservoir storage	Deliverablity/Cycling = 5 Cost Savings = 3 Safety and Security = 1 Capacity = 4 Environmental = 1 Reliability = 4.5
#5 Economic benefit to power consumers with enhanced storage infrastructure replace long-haul firm transport (FT)	Sensitivity analyses Demonstration at peaker and CC Review existing studies	Models (fuel) – Pipeline – Dispatch – Storage Result is economic model showing optimization for commodity and transportation	ISO regional studies OED at FERC (Office of Economic Development) Pipeline and storage companies	Any marketing company in U.S. Any IPP	Deliverablity/Cycling = 1 Cost Savings = 3.5 Safety and Security = 0 Capacity = 3.5 Environmental = 1 Reliability = 2.5

Agenda

NATURAL GAS STORAGE R&D WORKSHOP

U.S. DEPARTMENT OF ENERGY
NATIONAL ENERGY TECHNOLOGY LABORATORY
STRATEGIC CENTER FOR NATURAL GAS

Hyatt Regency Pittsburgh International Airport • Pittsburgh, Pennsylvania

Thursday, November 29, 2001

7:00 a.m.	Registration/Check-in & Continental Breakfast
8:00 a.m.	**Welcome/Overview** Brad Tomer, Product Manager, Gas Exploration, Production & Storage National Energy Technology Laboratory
8:15 a.m.	**DOE Gas Storage Program** Jim Ammer, Project Manager, Gas Supply Projects Division National Energy Technology Laboratory
8:30 a.m.	**Industry Perspectives** Gary Sypolt, Sr. Vice President, Transmission Dominion Transmission, Inc. Richard Daniel, Vice President, Storage and Hub Services Alberta Energy Company Ltd. Edmund Knolle, Executive Vice President Falcon Gas Storage Company Nathan Anderson, Principal Strategist, Strategy and Pricing El Paso Corporation George Bonner, President Energy East Enterprises, Inc.
9:45 a.m.	**Overview of Concurrent Breakout Sessions: Process and Products**
9:55 a.m.	*Break*
10:15 a.m.	**Breakout Sessions - Brainstorming the Issues** ♦ Conventional Gas Storage – Group A ♦ Conventional Gas Storage – Group B ♦ Gas Storage for Power Generation & Remote Off-Pipeline
11:00 a.m.	**Breakout Sessions - Analyzing the Opportunities** ♦ Conventional Gas Storage – Group A ♦ Conventional Gas Storage – Group B ♦ Gas Storage for Power Generation & Remote Off-Pipeline
12:30 p.m.	*Luncheon*
1:30 p.m.	**Breakout Sessions - Defining Action Recommendation Plans** ♦ Conventional Gas Storage – Group A ♦ Conventional Gas Storage – Group B ♦ Gas Storage for Power Generation & Remote Off-Pipeline
3:30 p.m.	*Break*
3:45 p.m.	**Plenary Regroup for Session Report-Outs**
4:15 p.m.	**Wrap-up**
4:30 p.m.	*Adjourn*

APPENDIX B
Participant List

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